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VOLUME I SUPPLEMENT I

OCTOBER 1963

X353-5B PROPULSION SYSTEM FLIGHTWORTHINESS TEST REPORT

(PENALTY TEST)

XV-5A

LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT NUMBER DA44-177-TC-715

GENERAL ELECTRIC

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VOLUME I, SUPPLEMENT I

Prepared By:

GENERAL ELECTRIC COMPANY

ADVANCED ENGINE AND TECHNOLOGY DEPARTMENT

Cincinnati 15, Ohio

TABLE OF CONTENTS

	PAGE
A. SUMMARY	1
B. TEST VEHICLE DESCRIPTION	3
1. Component Descriptions	3
2. Propulsion System Installation Arrrangement	5
3. Pre-Test Deviations	5
C. METHOD OF TEST	7
D. CALIBRATIONS	11
E. RECORD OF TEST	13
1. Test Run Chronology	13
2. Statistics of Testing	13
F. TEST DATA	17
1. Conditions of Test	17
2. Performance Results	20
3. Performance Comparisons versus X353-5B Specification	21
G. POST-TEST HARDWARE INSPECTION	23
H. ANALYSIS OF RESULTS	25
1. Hardware Evaluation	25
2. Performance Analysis	25
I. RECOMMENDATIONS	27
APPENDIX	
- Detailed Penalty Test Plan, Figures 1 through 35	29

LIST OF ILLUSTRATIONS

FIGURE		PAGE
1	New Rotor Torqueing Technique	35
2	Lift Fan Inlet Circular Vane Leading and Trailing Edge Weld Design Change	36
3	Lift Fan Exit Louver Arrangement (Left Fan)	37
4	Lift Fan Exit Louver Outboard Pin Attachment Design Change (Louver #37)	38
5	Lift Fan Exit Louver End Cap Design Change	39
6	In-Process View of Scupper Installation	40
7	Inside View of Rear Frame Scupper	41
8	Outside View of Rear Frame Scupper	42
9	Recess in Forward Air Seal for Rotor Inspection	43
10	Pitch Fan Ducting (Simulator Ducts Installed)	44
11	YJ85-5 Airflow versus Inlet Static Pressure	45
12	YJ85-5 EGT Harness Calibrations	46
13	Lift versus Scroll Inlet Ideal Horsepower	47
14	Fan Speed versus Scroll Inlet Ideal Horsepower	48
15	Gas Horsepower Available to Fan versus Engine Power	49
16	Lift versus Scroll Inlet Ideal Horsepower (Engine #1 only)	50
17	Fan Speed versus Scroll Inlet Ideal Horsepower (Engine #1 only)	51
18	Gas Horsepower Available to Fan versus Engine Power (Engine #1 only)	52
19	Lift versus Scroll Inlet Ideal Horsepower (Engine #2 only)	53
20	Fan Speed versus Scroll Inlet Ideal Horsepower (Engine #2 only)	54

FIGURE		PAGE
21	Gas Horsepower Available to Fan versus Engine Power (Engine #2 only)	55
22	Vertical Lift Ratio versus Indicated Louver Angle	56
23	Horizontal Thrust Ratio versus Indicated Louver Angle	57
24	Lift Fan Speed Ratio versus Indicated Louver Angle	58
25	Lift versus Engine Turbine Discharge Ideal Horsepower (Corrected to Specification 112 Conditions at 10.6% Bleed)	59
26	Fan Speed versus Engine Turbine Discharge Ideal Horsepower (Corrected to Specification 112 Conditions at 10.6% Bleed)	60
27	Comparison of Lift Fan 007L Speed-Lift Characteristics with Specification 112 ($\beta_v = 0^\circ$)	61
28	Torque Band Condition after Penalty Test	62
29	Seal Condition after Penalty Test	63
30	Bucket Carrier Condition after Penalty Test (Top Side)	64
31	Bucket Carrier Condition after Penalty Test (Bottom Side)	65
32	Platform Condition after Penalty Test	66
33	Scroll Where Hat Section was Added Showing Condition after Penalty Test	67
34	Flight Type Actuator for Diverter Valve	68
35	Lift Fan Exit Louver Outboard Pin Attachment Design Change (Louvers 34, 35 and 36)	69

LIST OF TABLES

TABLE	TITLE	PAGE
I	Lift and Thrust Accuracy	7
II	Instrumentation	9
III	Flightworthiness Penalty Test Chronology	14
IV	Test Statistics	15
V	Gas Power Distribution (Two Engine Operation)	18
VI	Gas Power Distribution (Single Engine Operation)	19
VII	X353-5B Performance Comparison with Specification 112 Sea Level Static Standard Day and 2500 Feet ANA 421 Standard Hot Day	22

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A. SUMMARY

The required 10-hour penalty test to evaluate design modifications to the X353-5B lift fan inlet vanes and aluminum exit louvers was completed in accordance with the schedule of test recommended to the Army in the X353-5B Propulsion System Flightworthiness Test Report. The test was completed on a slave X353-5B lift fan which was also an acceptance test vehicle.

This report is a supplement to the X353-5B Propulsion System Flightworthiness Test Report and documents the penalty test and results. It is submitted to the U.S. Army (TRECOM) in accordance with Specification 114 to form the basis for establishing a flightworthiness rating for the complete propulsion system including lift fan inlet vanes, aluminum exit louvers and diverter valves.

Upon completion of the test, the inspection results showed all lift fan components including inlet vanes and aluminum exit louvers to be in satisfactory condition.

The new rotor assembly technique recommended in the FWT Report and described in FRV Specification 124 was completely successful in avoiding fretting. Partial disassembly of the rotor following the test, witnessed by an Army (TRECOM) representative, showed all of the rotor hardware to be in excellent condition.

The XV-5A flight type diverter valve actuation successfully completed the penalty test plus two acceptance tests without incident and is in excellent condition.

All specific recommendations of the X353-5B Propulsion System Flightworthiness Test Report (Section I, 2, A through W) have been accomplished.

The General Electric Company recommends a flightworthiness rating be assigned to the X353-5B propulsion system including the X353-5B lift fan, X353-5B diverter valve and X376 pitch control fan.

B. TEST VEHICLE DESCRIPTION

1. COMPONENT DESCRIPTIONS

Diverter Valves: Diverter valves S/N 003L and 004R were previously used during the flightworthiness testing but were overhauled and fitted with a flight type actuation system just prior to the penalty test. Total accumulated time prior to overhaul included 29 hours from assurance tests and 81 hours from the flightworthiness test.

Lift Fan: The penalty test was run with the same lift fan configuration (left-hand-counter-clockwise rotation) as the flightworthiness test fan. The new rotor assembly technique recommended in the X353-5B Propulsion System Flightworthiness Test Report and described in FRV Specification 124 was used in assembling lift fan S/N 007L. The new carrier bolt torquing procedure is shown in Figure 1. The assembly was the first buildup for this set of parts and included new X353-5B lift fan inlet vanes and aluminum exit louvers.

Improved manufacturing processes as recommended in the FWT Report (Section I, 2, P) were used in making the new lift fan inlet vanes and exit louvers for the penalty test. Inlet vane skins were modified to provide for the improved welding configuration shown in Figure 2.

The exit louvers incorporated the following additional changes:

1. Exit louvers #38 and 13 (see Figure 3) are made into one louver and this louver (designated #13) is made of Inconel X material.

2. Louver #37 incorporated the design change shown in Figure 4 adding the solid aluminum stock to support the longer pin on the outboard end of the louver near the hot gas stream. Early in the test a slight bend developed at the outboard end of louver #37. In-

spection of the louver indicated that the design change specified in Figure 4 had not been complied with in manufacture; the pivot pin was not replaced by a longer pin to extend all the way into the aluminum block. The louver was removed from the fan (after 2 hours, 56 minutes operation) and this deficiency was corrected. No further problems were encountered with louver #37.

3. Rivets were added to all aluminum louvers as shown in Figure 5.

A "scupper" was installed in the fan rear frame to serve as a catch for foreign objects that might otherwise tumble around in this region causing extensive damage to the turbine buckets before finding a way out. This very situation occurred at the beginning of acceptance test #2 (LF 005L) and this scupper installation has now been added to all lift fans in the FRV program. Figure 6 shows an in-process view of the scupper installation which is simply a pocket forming a by-pass around the tip of the turbine. Inside and outside views of the completed installation are shown in Figures 7 and 8, respectively.

To aid in making a more complete inspection of the rotor in the installed fan assembly, a recess has been cut into the forward air seal as shown in Figure 9. The opening is 2 inches long and, to minimize any effect on performance, it is located under the outboard strut (inactive arc). The forward face of the bucket carriers including the carrier bolts can be viewed through this opening.

<u>Pitch Fan</u>: Pitch fan simulator ducts were installed in place of a pitch fan. The hot gases from the pitch fan ducts are discharged overboard through the simulator ducts in such a way as to eliminate any thrust contribution to the system. In Figure 10, the simulator ducts are shown in the installed condition.

2. PROPULSION SYSTEM INSTALLATION ARRANGEMENT

The X353-5B propulsion system arrangement in General Electric's Evendale Test Facility is described in detail in Volume I of the Flightworthiness Test Report. For the Penalty Test, the system consisted of the following items:

Lift Fan	- X353-5B S/N 007L (B/U 1)
Pitch Fan Simulator Ducts	- Test Equipment
Diverter Valve Position #1	- X353-5B S/N 003L (B/U 3)
Diverter Valve Position #2	- X353-5B S/N 004R (B/U 3)
Cross Duct Position #1	- Ryan S/N 001
Cross Duct Position #2	- Ryan S/N 002
Pitch Fan Duct Position #1	- Ryan S/N 001
Pitch Fan Duct Position #2	- Ryan S/N 002
Engine #1	- YJ85-GE-5 (S/N 230167)
Engine #2	- YJ85-GE-5 (S/N 230161)

YJ85-GE-5 gas generators were used for the penalty test in accordance with test Specification 116 and U.S. Army (TRECOM).

3. PRE-TEST DEVIATIONS

Except for the items described on the next page, all of the pre-test deviations were the same as reported for the FWT.

a) Pitch fan simulator ducts were used in place of a pitch fan.

b) Flight type actuators and linkage installed on diverter valves during this test.

C. METHOD OF TEST

The thrust frame and measurement system are described in Volume I of the X353-5B Propulsion System Flightworthiness Test Report. The lift and thrust accuracies reported in the FWT report are unchanged and are given in the following table.

TABLE I

LIFT AND THRUST ACCURACY

	System Lift	Lift Fan Lift	Pitch Fan Lift	Horizontal Thrust
Load Cell Calibration	± 0.45%	N/A	N/A	± 0.71%
Test Data Accuracy*	± 0.94%	± 1.71%	± 1.94%	± 1.94%
Overall Accuracy	± 1.39%	± 1.71%	± 1.94%	± 2.65%

*95% Confidence limits, neglecting wind effects, based on 2σ spread determined from 13 data points.

The tabulated values of lift fan and pitch fan lift measurement accuracies are applicable only if both fans are included in the system. When this is the case, pitch fan lift is calculated from an equation (see FWT Report) involving total system lift, measured lift from the nose load cell and system geometry. Lift fan lift is then determined by subtracting pitch fan lift from total system lift and the corresponding measurement accuracy is listed in Table I as 1.71%.

For the penalty test configuration with no pitch fan installed, total measured system lift and lift fan lift are synonymous and the measurement accuracy is ± 1.39% as shown in Table I.

Essentially the same test equipment was required for this test as the FWT but there were some changes in instrumentation. The total instrumentation provided for this test is listed in Table II.

A detailed penalty test plan was prepared (included in the Appendix) based on the schedule of test recommended to the Army in the X353-5B Propulsion System Flightworthiness Test Report.

The order of the test was as follows:

		Hr:Min.
Run #1	Mechanical Checkout and Performance Calibration	0:49
Run #1	Cycle #1, Parts I and II	2:07
Run #2	Cycle #2, Parts I and II	2:08
Run #2	Cycle #3, Part I - Shut down to avoid exceeding neighborhood noise levels for this time of day (9 PM).	1:07
Run #3	Cycle #3, Part II	1:04
Run #3	Cycle #4, Part I and II	2:05 1/2
Run #3	Cycle #5, Part I and II	2:16 1/2*
Run #4	Initial Acceptance Test	0:55
Run #4	Final Acceptance Test	0:46
Run #4	Performance Recalibration	2:03
Run #5	Louver Performance Investigation	0:45
Total Fan Time		16:06

* Went off schedule for 5 minutes to take two performance points at low wind conditions.

TABLE II
INSTRUMENTATION

Item	Location	Plane	Sensor	Readout	Quantity	Purpose
1	Engine inlet	2.0	Static pressure (wall)	100 in. H_2O mano	4[a]	Engine flow measurement.
2	Engine inlet	2.0	Total temperature (CA)	Digital mv recorder	3[a]	Engine flow measurement; correcting engine performance.
3	Engine turbine discharge	5.1	*Total temperature (CA)	Weston meter and Digital mv recorder	1[a]	Monitor engine performance and engine power.
4	Engine turbine discharge	5.1	Total pressure	60 in. H_g mano	21[a]	Engine power.
5	Engine turbine discharge	8.0	Total temperature (CA)	Digital mv recorder	32[c]	Calibrate station 5.1 EGT harness.
6	Pitch fan scroll inlet	15.3	Total pressure	60 in. H_g mano	1[a]	Power and weight flow to the pitch fan.
7	Pitch fan scroll inlet	15.3	Static pressure (wall)	100 in. H_2O mano ΔP with $P_{T15.3}$	3[a]	Weight flow to the pitch fan.
8	Overboard flow	5.3	Total temperature (CA)	Digital mv recorder.	9[a]	Weight flow overboard.
9	Overboard flow	5.3	Static pressure (wall)	0-60 in. H_g mano	3[a]	Weight flow overboard.
10	Overboard flow	5.3	Total pressure	0-100 in. H_2O mano	13[a]	Weight flow overboard.
11	Slipring (fan)	-	Total temperature (CA)	Dial gage 0-300°F	1[b]	Bearing temperature.
12	Lift fan inlet temperature	10.0	Total temperature (CA)	Digital mv recorder	12	Correcting fan performance.
13	Pitch fan duct	-	**Sound probe	Tape recorder	1[b]	Sound pressure level.
14			*Compressor discharge static pressure	Koleman gage 0-200 in. H_g	1[a]	Monitor engine performance.
15			*Lift fan bearing T.C. (CA)	0-400°F (CA) gage	2[b]	Fan bearing temperature.
16			*Flow potter	Berkley	1[a]	Fuel flow.
17			*Engine oil temperature (CA)	0-400°F (CA) gage	2 or 3[a]	Engine oil temperature.
18			*Fuel pressure transducer	0-600 psig gage	1[a]	Fuel control pressure.
19			*Oil pressure transducer	0-200 psig gage	1[a]	Oil pressure.
20			*Engine tach generator	0-18,000 rpm tach	1[a]	Engine speed.
21			*Fan speed pickup	Tach, Sanborne, and Berkley	1[b]	Fan speed.
22			*Engine vibrations	0-10 mils with 70 cycle filter	4[a]	Engine vibes.
23			*Fan vibrations	0-20 mils with 10 cycle filter	2[b]	Fan vibes.
24			*Throttle position	Selsyn gage	1[a]	Throttle position.
25			*Diverter valve position micro switch	Light, on and off indicator	1[a]	Diverter valve position.
26			*Exit louver position	Selsyn gage -30° to +60°	2[b]	Exit louver position.
27	Lift fan rotor		**Blade strain gage		8	Stress measurement.

[a]Two sets required - one per engine. [b]One set only. [c]Used on each engine to calibrate the EGT harness.

*Operational instrumentation. **Research instrumentation.

D. CALIBRATIONS

All sensors and system calibration methods and test accuracies are the same as described in Volume I, X353-5B Propulsion System Flightworthiness Test Report.

Load cell calibrations showed that there were no corrections to be applied to the indicated load cell readings.

System performance was calculated from data taken during Runs 1, 3, 4 and 5. Performance calibrations were Runs 1 and 4; two data points at low wind conditions were evaluated from Run 3; and data points were taken during Run 5 with and without exit louvers.

YJ85 bellmouth flow calibrations and EGT harness calibrations are shown in Figures 11 and 12, respectively.

Ambient conditions are measured in the same manner as during the FWT.

E. RECORD OF TEST

1. TEST RUN CHRONOLOGY

Table III presents the test run chronology operating times and significant events and observations.

2. STATISTICS OF TESTING

Table IV is a summary of operating statistics defining the general content of endurance testing accomplished.

TABLE III

FLIGHTWORTHINESS PENALTY TEST CHRONOLOGY

Run No.	Date	Lift Fan (007) Time (hrs:mins.)	Lift Fan (007) Total Time (hrs:mins.)	Diverter Valve (003) Time (hrs:mins.)	Diverter Valve (003) Total Time (hrs:mins.)	Diverter Valve (004) Time (hrs:mins.)	Diverter Valve (004) Total Time (hrs:mins.)	Remarks
1	4/2/63	2:56	2:56	3:59	3:59	3:56	3:56	Mechanical checkout of engines and fan. Set engine high speed stops. Adjusted areas to give rated EGT at 100% rpm. Performance calibration run completed. Ran cycle #1 of FWT penalty test. Leak in hydraulic line to #2 diverter valve after Part I of the penalty test; this was repaired and test continued. Beta 2 selsyn system (position indicator) became inoperative near end of Part II of penalty run. Since the remaining test schedule was at this same louver position, cycle #1 of the penalty test was continued and completed.
2	4/4/63	3:15	6:11	3:47	7:46	3:32	7:28	At end of Run 1, louver #37 was removed to correct manufacturing deviation (longer pivot pin not installed). Cycle #2 of penalty test was completed. During idle inspection at end of cycle #2, it was noted that fuel line coming from main fuel control to overspeed governor was leaking. This was replaced and the test was continued. Cycle #3 was interrupted after 1 hour and 1 minute of running to avoid exceeding neighborhood noise levels for that time of day (9 o'clock).
3	4/5/63	5:26	11:37	6:02	13:48	6:13	13:41	Cycle #3 of penalty run was completed. After idle inspection, the penalty run continued on cycle #4. Cycles #4 and #5 of penalty run were completed. During cycle #5, went off schedule long enough to take two readings to check performance at low wind conditions. Fan, exit louvers and circular vane were inspected and found to be in satisfactory condition at the end of the 10 hour penalty test.
4	4/9/63	3:44	15:21	4:05	17:53	4:03	17:44	Completed Initial and Final Acceptance Tests. Ran performance recalibration including exit louver vector data from β_v of -15° to $+45^\circ$.
5	4/10/63	0:45	16:06	1:05	18:58	1:02	18:46	Took three readings at maximum power with louvers set at $\beta_{avg} = 0^\circ$, $\beta_s = 2^\circ$. Completed VIP Demonstration Run. Removed exit louvers and ran six performance points at maximum power to determine loss in lift caused by installation of louvers.

TABLE IV

TEST STATISTICS

Item	Lift Fan 007	Diverter Valve 003	Diverter Valve 004
Time at Max. Power, hrs.	13.4	13.9	13.9
Single Engine Operation, hrs.	0.8	-	-
Time at Critical Speed, hrs.	1.3	-	-
Throttle Bursts	17	18	18
Throttle Chops	18	19	19
Thrust/Lift Conversions	45	45	45
Lift/Thrust Conversions	44	44	44
Starts	-	17	18
Maximum Test Speed, rpm	2608	-	-

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F. TEST DATA

The net weight of the lift fan 007L assembly including research instrumentation was 814 pounds. Comparable weight of lift fan 003L used for the flightworthiness test was 807.4 pounds. Approximately 4 pounds of the increased weight on LF 007L is due to the new exit louvers incorporating the changes in manufacturing and material as recommended in the FWT report.

1. CONDITIONS OF TEST

Flow Split: The lift fan scroll areas were set at their maximum values and the overboard bleed system areas were adjusted to establish rated EGT. The pitch fan simulators were installed with an area that resulted in approximately 9.5% bleed flow to the pitch fan ducts. Tables V and VI show the gas power distribution experienced during the FWT penalty test.

Wind Condition: Average wind conditions for each of the runs were as follows:

Run #	Average Wind Conditions
1	10 mph at 200°
2	10 mph at 320°
3	7 mph at 150°
4	15 mph at 330°
5	8 mph at 15°

TABLE V

GAS POWER DISTRIBUTION
(TWO ENGINE OPERATION)

Parameter	Units	Engine #1	Engine #2
Reading		81	81
$N_{J85}/\sqrt{\theta_2}$	%	98.63	98.44
$W_2\sqrt{\theta_2}/\delta_2$	lb/sec.	43.23	42.38
W_2	lb/sec.	41.54	40.64
W_f	lb/hr.	2421	2406
$W_{5.1}$	lb/sec.	42.21	41.31
$W_{5.1}$ - Leakage	lb/sec.	41.87	40.98
$T_{5.1}$	^oR	1666	1633
$(P_t/P_s)_{5.3}$		1.166	1.152
$W_{5.3}$	lb/sec.	18.81	18.56
$(P_t/P_s)_{15.3}$		1.029	1.028
$W_{15.3}$	lb/sec.	4.09	3.88
W_{LF}	lb/sec.	18.97	18.54
$W_{5.3}$	%	44.93	45.29
$W_{15.3}$	%	9.77	9.46
W_{LF}	%	45.30	45.25
$N_{LF}/\sqrt{\theta_{10}}$	%	92.09	
L_{LF}/δ_2	lb.	6172	

TABLE VI

GAS POWER DISTRIBUTION
(SINGLE ENGINE OPERATION)

Parameter	Units	Engine #1	Engine #2
Reading		88	99
$N_{J85}/\sqrt{\theta_2}$	%	99.3	99.3
$W_2\sqrt{\theta_2}/\delta_2$	lb/sec.	43.45	42.71
W_2	lb/sec.	42.03	41.31
W_f	lb/hr.	2473	2473
$W_{5.1}$	lb/sec.	42.72	42.00
$W_{5.1}$ - Leakage	lb/sec.	42.38	41.67
$T_{5.1}$	^oR	1663	1635
$(P_t/P_s)_{5.3}$		1.168	1.155
$W_{5.3}$	lb/sec.	19.06	18.85
$(P_t/P_s)_{15.3}$		1.028	1.029
$W_{15.3}$	lb/sec.	4.01	3.99
W_{LF}	lb/sec.	19.31	18.83
$W_{5.3}$	%	44.97	45.24
$W_{15.3}$	%	9.46	9.58
W_{LF}	%	45.57	45.18
$N_{LF}/\sqrt{\theta_{10}}$	%	71.21	69.77
L_{LF}/δ_2	lb.	3671	3590

2. PERFORMANCE RESULTS

The gas generators used for the FWT penalty test were YJ85-GE-5 engines having a turbine discharge flow function $\left(\frac{W\sqrt{T}}{P}\right)_{5.1}$ of 57.0. For ARDC sea level standard day conditions, the EGT at military rating was 1654°R.

The measured results from the performance calibration (Run #1) and the performance recalibration (Run #4) are presented in Figures 13 through 21. To obtain the maximum possible fan lift and speed at the YJ85 engine power levels, maximum lift fan scroll area settings were used. All curves showing fan characteristics extended beyond measured results are generated from the ideal fan law relationships $(N^3 \alpha F^{3/2} \alpha HP)$.

Fan lift and speed are presented as a function of scroll inlet ideal horsepower in Figures 13 and 14. At this scroll area setting, the lift fan received 45.33% of the total available flow which corresponds to a system bleed setting of 9.34%. Figure 15 gives the relationship of the gas horsepower supplied by the engine to the gas horsepower available at the fan scroll inlet for the test bleed setting.[a]

The measured lift fan data corrected to the 10.6% bleed setting and to the Specification 112 J85-5 engine turbine discharge flow function ($W\sqrt{T}/P$ = 54.64) are presented as a function of gas horsepower available at engine discharge in Figures 25 and 26. Figure 27 shows the corresponding fan speed-lift characteristics.

More extensive performance data were taken for single engine operation during the performance recalibration (Run #4). Measured results are shown in Figure 16 through 18 for operation of engine #1 only and in

[a]Lift fan scroll inlet ideal horsepower is based on pressure loss measurements obtained during scale model cross duct/scroll aerodynamic tests (cold air).

Figures 19 through 21 for engine #2 only.

Also during the performance recalibration run, performance data were taken at constant engine throttle setting for exit louver vector angles from -15^{o} to $+45^{o}$. Figures 22 through 24[a] show the resulting variation of lift, horizontal thrust and fan speed corrected to constant scroll inlet ideal horsepower. Ram drag corrections for both the lift fan and engine were applied in all cases to the lift fan horizontal thrust values based on wind conditions as recorded during the test.

3. PERFORMANCE COMPARISON VERSUS X353-5B SPECIFICATION

Figure 27 shows the calibration and recalibration results as well as the Specification 112 fan lift-speed characteristic. Figures 25 and 26 gives fan lift and speed as a function of engine turbine discharge ideal horsepower. Using the J85-5 engine horsepower-speed characteristic (Figure 32, Specification 112), the fan characteristics can be determined at any desired engine rating. In this way, the data for Table VII were generated to provide a direct comparison with the specification rating points.

[a]These figures represent the best available data on the X353-5B lift fan characteristics as a function of exit louver angle and supersedes all previously published information.

TABLE VII

X353-5B PERFORMANCE COMPARISON WITH SPECIFICATION 112
SEA LEVEL STATIC STANDARD DAY AND 2500 FT. ANA 421 STANDARD HOT DAY

Ratings (Turbojet Power Setting)	Military	Military Single Engine	95% RPM	90% RPM	85% RPM
Spec. Turbojet Rotor RPM (Max.)	16,500	16,500	15,675	14,850	14,025
Sea Level Static Standard Day					
Ideal Horsepower at Turbojet Turbine Discharge, $HP_{5.1}/\delta_2\sqrt{\theta_{10}}$ (Figure 32, Spec. 112)	5,310	5,310	3,640	1,860	1,100
Spec. Lift Fan Rotor RPM (Max.)	2,602	2,020	2,304	1,817	1,521
Calibration	2,556	-	2,247	1,779	1,463
Recalibration	2,595	1,942	2,284	1,803	1,486
Spec. Lift Fan Thrust, lbs. (Min.)	6,570	3,915	5,172	3,237	2,273
Calibration	6,990	-	5,420	3,380	2,300
Recalibration	6,990	3,994	5,420	3,380	2,300
2500 Ft. Altitude and 421 Standard Hot Day					
Ideal Horsepower at Turbojet Turbine Discharge, $HP_{5.1}/\delta_2\sqrt{\theta_{10}}$ (Figure 32, Spec. 112)	4,460	4,460	2,390	1,375	850
Spec. Lift Fan Rotor RPM (Max.)	2,510	1,944	2,077	1,696	1,451
Calibration	2,487	-	2,004	1,652	-
Recalibration	2,525*	1,889	2,037	1,682	-
Spec. Lift Fan Thrust, lbs. (Min.)	5,282	3,130	3,639	2,435	1,783
Calibration	5,693	-	3,715	2,492	-
Recalibration	5,693*	3,256	3,715	2,492	-

*At Spec. fan rotor RPM of 2510, lift fan thrust is 5628 lb., and turbojet power is reduced slightly.

G. POST-TEST HARDWARE INSPECTION

Upon completion of the FWT penalty test, lift fan 007L was partially disassembled for inspection. The rear frame and rotor were removed and the rotor was partially disassembled. The inlet vane and exit louvers were removed and zygloed.

The results of the inspection were as follows:

1. The inlet vane had no defects.

2. All parts of the rotor were in excellent condition. Photographs of the torque band, seal, bucket carrier and platform are included in Figures 28 through 32.

3. All of the exit louvers were in good condition but louvers 35 and 36 (Figure 3) were found to be slightly bent at the outboard end near the hot gas stream.

4. The external hat section added to the lift fan scroll in the region between the hot gas inlets is shown in Figure 33. No indications of buckling were found.

5. The XV-5A flight type diverter valve actuation successfully completed the penalty test plus two acceptance tests without incident and was still in excellent condition. A view of the actuator is shown in Figure 34.

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H. ANALYSIS OF RESULTS

1. HARDWARE EVALUATION

There were no failures during the FWT penalty test.

The post-test hardware inspection did reveal that aluminum louvers 35 and 36 were slightly bent at the outboard end near the hot gas stream. This was caused by the long soak-in time to achieve the penalty test schedule which required concentrated running at high power settings to subject the louvers to high vector air load conditions. Even though the louvers did complete the test in satisfactory condition, it was decided to incorporate a design change on louvers 34, 35 and 36 similar to the one used on louver 37 (see Figure 35). A longer aluminum block was added to retain the pivot pin to prevent the slight bending during hot gas impingement on the outer end of the louver. The integrity of this design[a] was verified on louver 37 which completed the penalty test with no distortion at the outboard end.

2. PERFORMANCE ANALYSIS

Lift fan performance corrected to Specification 112 power and bleed conditions are given in Table VII.

The results at standard day military power show the lift fan to exceed Specification 112 by 6.4% in lift. Generally, the lift fan exceeded specification levels at all other rating conditions.

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[a]Two sets of exit louvers, one set with and one set without the modification to louvers 34, 35 and 36 have successfully completed tests since the FWT penalty run. The set without the modification completed 4 hours and 55 minutes of testing on LF 006R; the modified set completed 12 hours and 56 minutes of testing on LF 008R.

Comparing lift fan characteristics between the performance calibration and recalibration, there is no apparent deterioration in performance. Lift-power data (Figure 13) shows very close agreement but speed-power data (Figure 14) indicates that the fan speed was 1.5% higher at the same power level for the recalibration run. This effect is caused by the different wind conditions present during these tests and results in the different fan lift-speed characteristics shown in Figure 27. Similar variation of lift fan power absorption with wind was present in the FWT data and has been discussed in TREC Technical Report 62-21 based on test results of the X353-5A lift fan.

Single engine performance simulating either one engine out or sequential diverter valve operation for conversion provided 57.1% of the maximum power actual thrust level compared to the Specification 112 value of 59.6% of rated thrust. The actual single-engine thrust exceeded the specification rating by 2% because of the generally higher level of performance obtained.

I. RECOMMENDATION

The General Electric Company recommends the U.S. Army (TRECOM) approve a flightworthiness rating for the X353-5B propulsion system including the X353-5B lift fan, X353-5B diverter valve and X376 pitch control fan based on the accomplishment of the 10-hour penalty test and all specific recommendations of the X353-5B Propulsion System Flightworthiness Test Report (Section I, 2, A through W).

A P P E N D I X

FWT PENALTY TEST PLAN

Step	Action or Condition	Time Min:Sec.	β_1	β_2	Reading	Acc. Time Hr:Min:Sec.	Remarks
1	Start engines - cruise	--	-1	+1			
2	Idle - Cruise		-1	+1	G		Visual inspection
3	Switch to Takeoff		-1	+1			
4	Accel to 100%		-1	+1			
5	Max. Speed	1:40	-1	+1		00:01:40	
6	β_1 to -19°, β_2 to +19	0:20	-19	+19		00:02:00	Move β_2 carefully
7	β_s 38°, β_v 0°, Max. N_{LF}	1:40	-19	+19		00:03:40	
8	β_2 to +10, β_1 to -10	0:20	-10	+10		00:04:00	
9	β_s 20°, β_v 0°, Max. N_{LF}	1:40	-10	+10		00:05:40	
10	β_1 to 0°, β_2 to 20°	0:20	0	+20		00:06:00	
11	β_s 20°, β_v 10°, Max. N_{LF}	1:40	0	+20		00:07:40	
12	β_1 to +10, β_2 to +30°	0:20	+10	+30		00:08:00	
13	β_s 20°, β_v 20°, Max. N_{LF}	1:40	+10	+30		00:09:40	
14	β_2 to +31°, β_1 to +29°	0:20	+29	+31		00:10:00	Move β_1 carefully
15	β_s 2°, β_v 30°, Max. N_{LF}	1:40	+29	+31		00:11:40	

FWT PENALTY TEST PLAN (Continued)

Step	Action or Condition	Time Min:Sec.	β_1	β_2	Reading	Acc. Time Hr:Min:Sec.	Remarks
16	β_2 to +41, β_1 to +39	0:20	+39	+41		00:12:00	Move β_1 carefully
17	β_s 2^o, β_v 40^o, Max. N_{LF}	1:40	+39	+41		00:13:40	
18	β_2 to $+46^o$, β_1 to $+44^o$	0:20	+44	+46		00:14:00	Move β_1 carefully
19	β_s 2^o, β_v 45^o, Max. N_{LF}	2:00	+44	+46		00:16:00	
20	β_1 to $+39^o$, β_2 to $+41^o$	0:20	+39	+41		00:16:20	Move β_2 carefully
21	β_s 2^o, β_v 40^o, Max. N_{LF}	1:40	+39	+41		00:18:00	
22	β_1 to +29, β_2 to $+31^o$	0:20	+29	+31		00:18:20	Move β_2 carefully
23	β_s 2^o, β_v 30^o, Max. N_{LF}	1:40	+29	+31		00:20:00	
24	β_1 to +10, β_2 to $+30^o$	0:20	+10	+30		00:20:20	
25	β_s 20^o, β_v 20^o, Max. N_{LF}	1:40	+10	+30		00:22:00	
26	β_2 to $+20^o$, β_1 to 0^o	0:20	0	+20		00:22:30	
27	β_s 20^o, β_v 10^o, Max. N_{LF}	1:40	0	+20		00:24:00	
28	β_2 to $+10^o$, β_1 to -10^o	0:20	-10	+10		00:24:20	
29	β_s 20^o, β_v 10^o, Max. N_{LF}	1:00	-10	+10		00:25:20	

FWT PENALTY TEST PLAN (Continued)

Step	Action or Condition	Time Min:Sec.	β_1	β_2	Reading	Acc. Time Hr:Min:Sec.	Remarks
30	β_1 to $+5^o$, β_2 to $+25^o$						
	β_1 to $+20^o$, β_2 to $+36^o$						
	β_1 to $+34^o$ carefully	0:40	+34	+36		00:26:00	
31	β_s 2^o, β_v 35^o, Max. N_{LF}	12:30	+34	+36	G @ 3M	00:38:30	
32	Switch to cruise	0	+34	+36		00:38:30	
33	Cruise	0:30	+34	+36		00:39:00	
34	Switch to Takeoff	0	+34	+36		00:39:00	
35	β_s 2^o, β_v 35^o, Max. N_{LF}	4:30	+34	+36		00:43:30	
36	Switch to cruise	0	+34	+36		00:43:30	
37	Cruise	0:30	+34	+36		00:44:00	
38	Switch to Takeoff	0	+34	+36		00:44:00	
39	β_s 2^o, β_v 35^o, Max. N_{LF}	4:30	+34	+36		00:48:30	
40	Switch to cruise	0	+34	+36		00:48:30	
41	Cruise	0:30	+34	+36		00:49:00	

FWT PENALTY TEST PLAN (Continued)

Step	Action or Condition	Time Min:Sec.	β_1	β_2	Reading	Acc. Time Hr:Min:Sec.	Remarks
42	Switch to Takeoff	0	+34	+36		00:49:00	
43	β_s 2°, β_v 35°, Max. N_{LF}	4:30	+34	+36		00:53:30	
44	Switch to cruise	0	+34	+36		00:53:30	
45	Cruise	0:30	+34	+36		00:54:00	
46	Switch to Takeoff	0	+34	+36		00:54:00	
47	β_s 2°, β_v 35°, Max. N_{LF}	7:00	+34	+36	G @ 2M	01:01:00	
48	Chop to Idle	0:10	+34	+36		01:01:10	
49	β_s 2°, β_v 35°, Idle	1:40	+34	+36		01:02:50	
50	TB to Max.	0:10	+34	+36		01:03:00	
51	β_s 2°, β_v 35°, Max. N_{LF}	11:40	+34	+36		01:14:40	
52	β_2 to +46°, β_1 to +44°	0:20	+44	+46		01:15:00	Move β_1 carefully
53	β_s 2°, β_v 45°, Max. N_{LF}	20:00	+44	+46	G @ 15M	01:35:00	
54	Decel to 2200 rpm N_{LF}	0:20	+44	+46		01:35:20	
55	β_s 2°, β_v 45°, 2200 rpm N_{LF}	9:20	+44	+46		01:44:40	

FWT PENALTY TEST PLAN (Continued)

Step	Action or Condition	Time Min:Sec.	β_1	β_2	Reading	Acc. Time Hr:Min:Sec.	Remarks
56	Accel to Max. N_{LF}	0:20	+44	+46		01:45:00	
57	β_s 2°, β_v 45°, Max. N_{LF}	20:00	+44	+46	G @ 15	02:05:00	
58	Switch to cruise	0	+44	+46		02:05:00	
59	Decel to Idle	0:30	+44	+46		02:05:30	
60	Idle - Cruise	4:30	+44	+46		02:10:00	Visual inspection
	SHUTDOWN	0	+44	+46		02:10:00	
	Penalty Schedule Part 1 and Part 2 Complete						

The FWT penalty test consisted of five (5) cycles of the above schedule which resulted in a little more than 10 hours of test time.

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TOP LOOKING DOWN

-||- = TORQUE BAND GAP

H = 35 LB IN TORQUE

L = 25 LB IN TORQUE

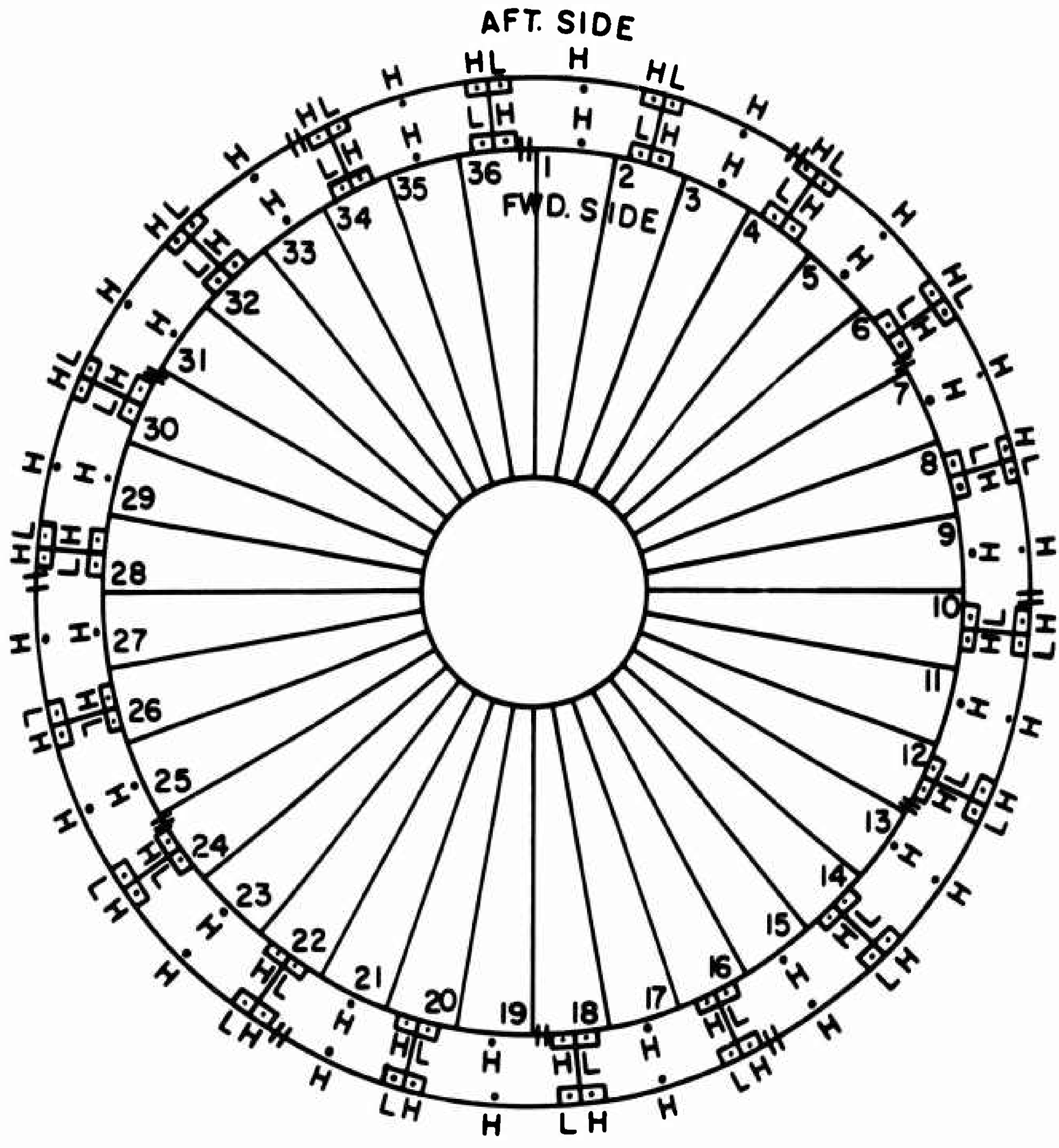


Figure 1 New Rotor Torqueing Technique

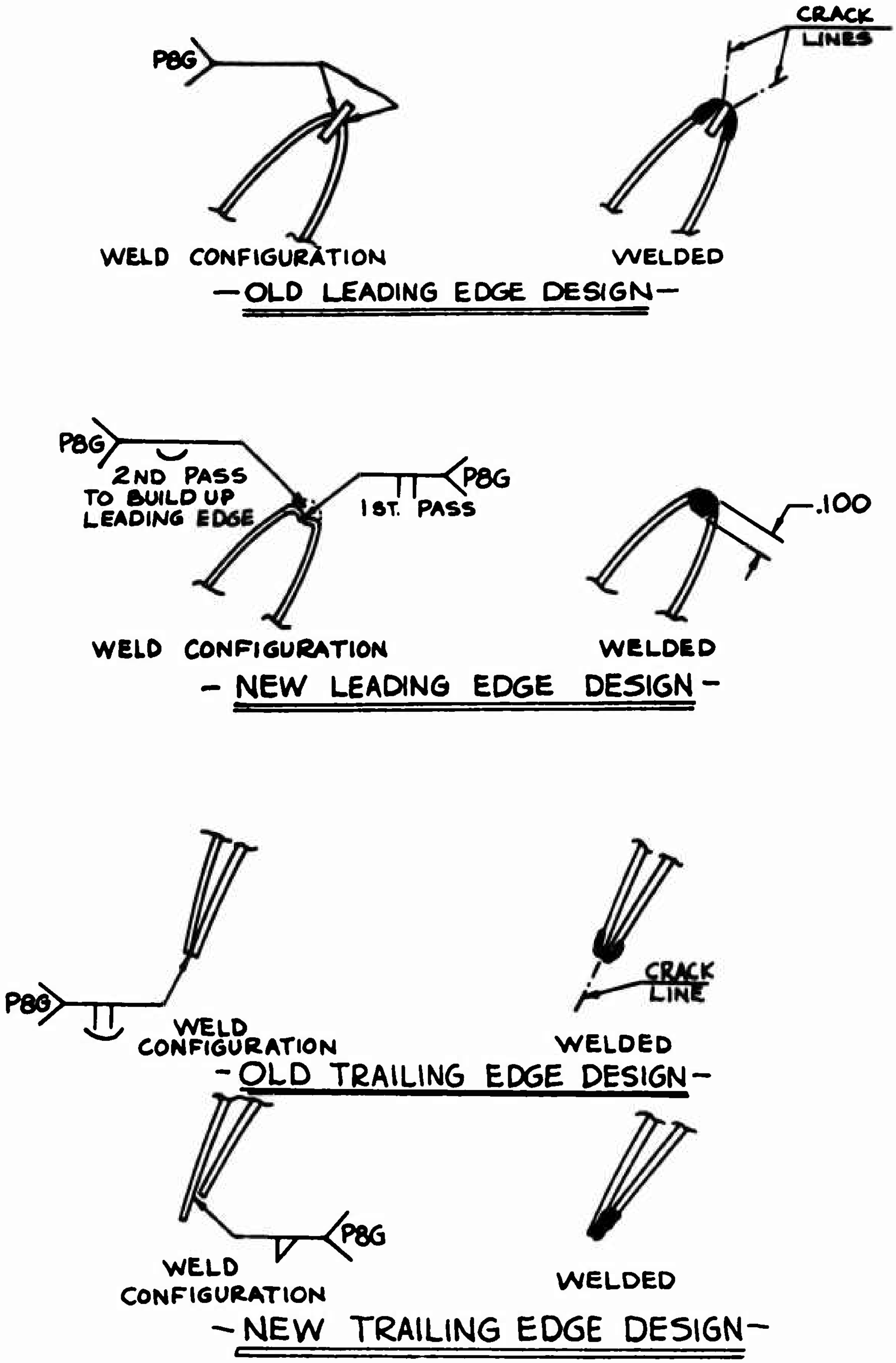


Figure 2 Lift Fan Inlet Circular Vane Leading and Trailing Edge Weld Design Change

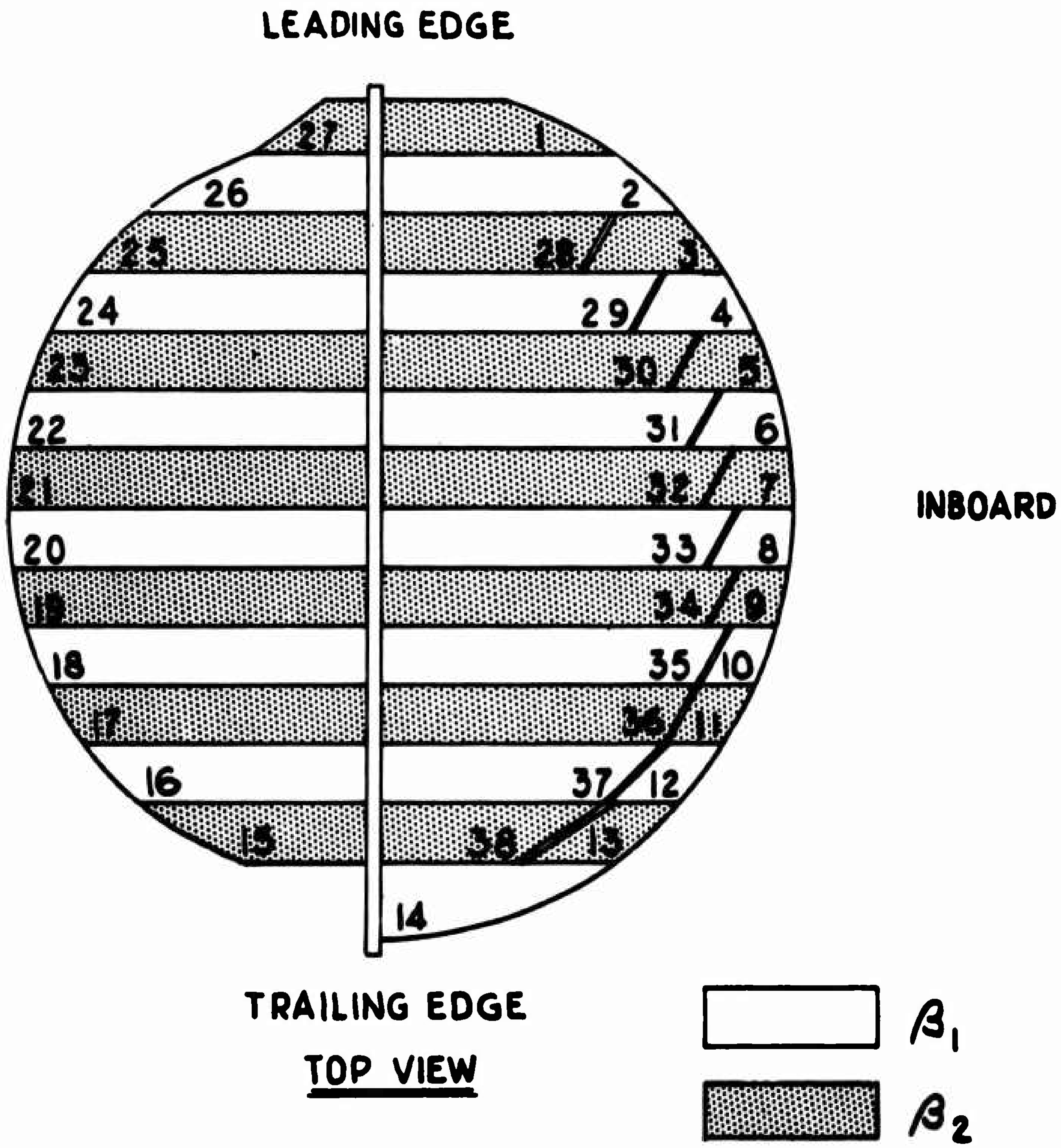
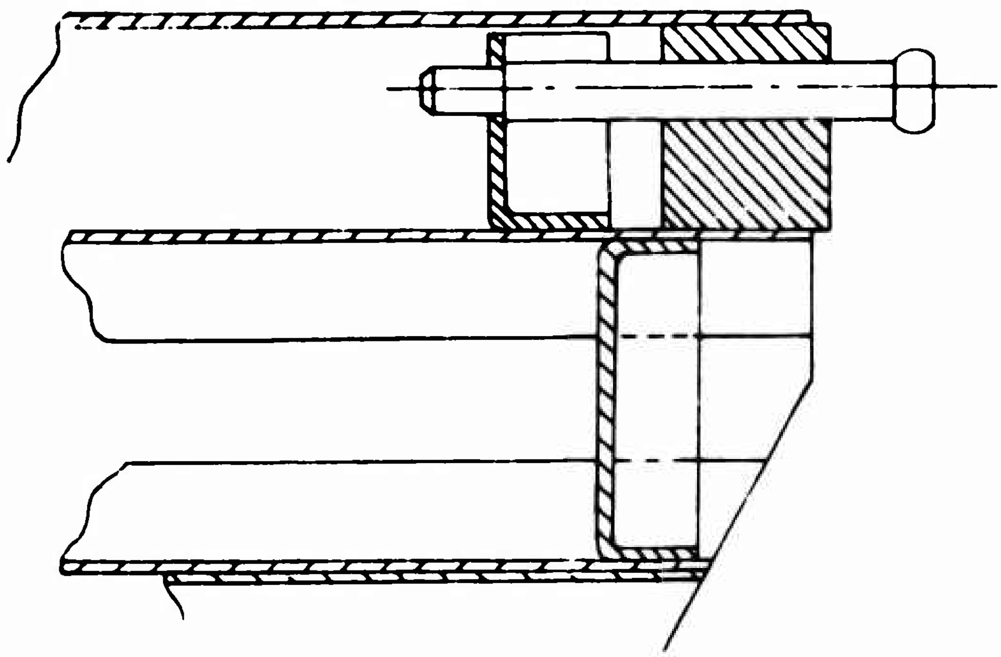
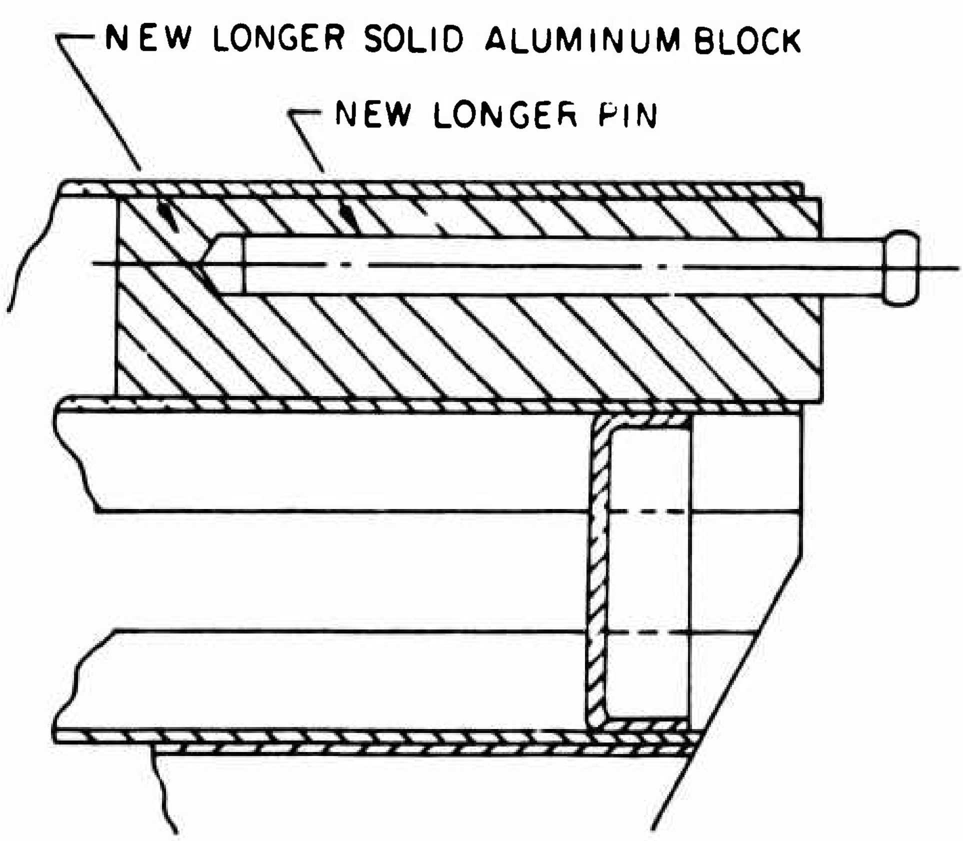


Figure 3 Lift Fan Exit Louver Arrangement (Left Fan)



OLD OUTBOARD PIN ATTACHMENT DESIGN



NEW OUTBOARD PIN ATTACHMENT DESIGN

Figure 4 Lift Fan Exit Louver Outboard Pin Attachment Design Change (Louver #37)

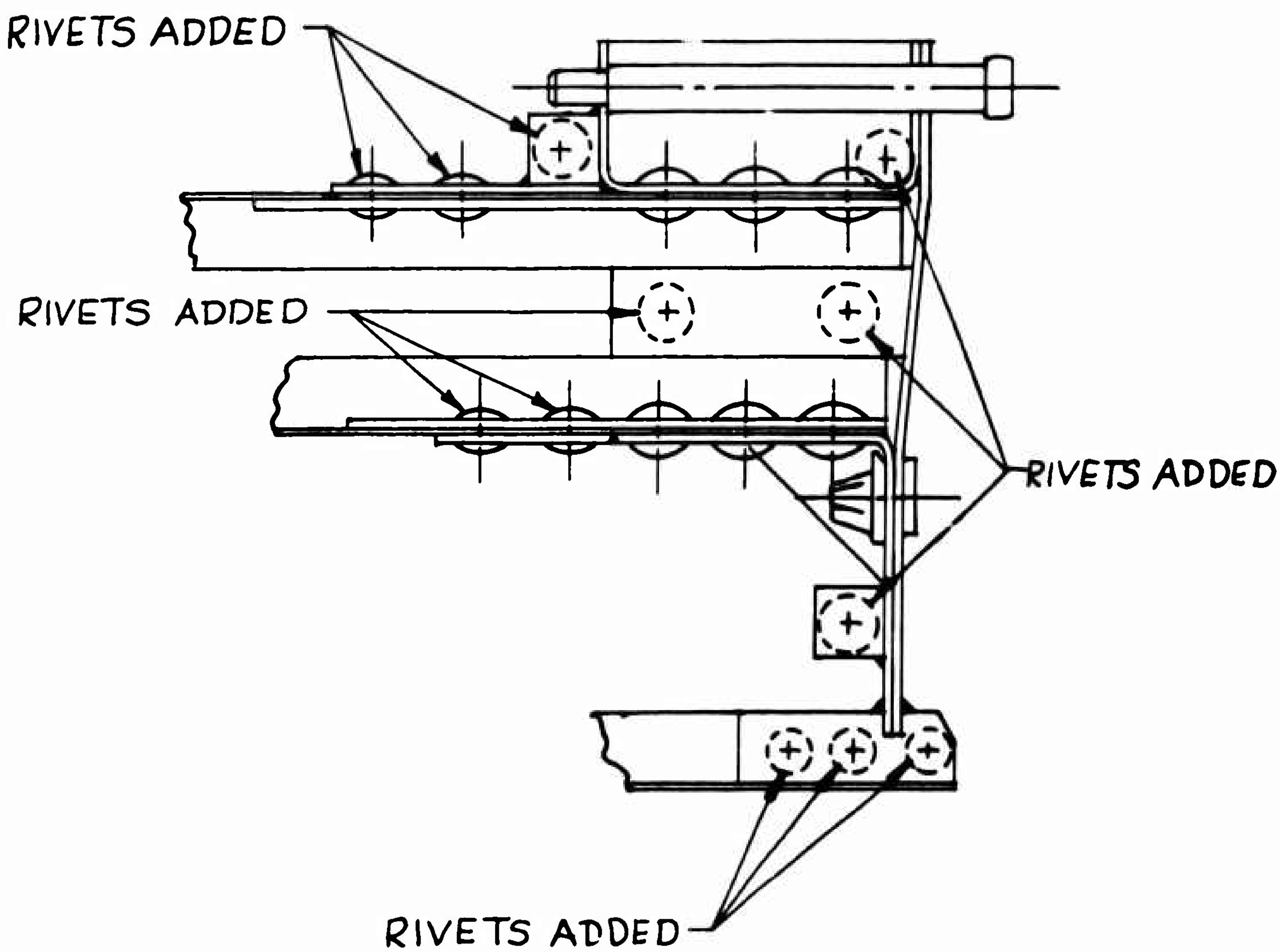


Figure 5 Lift Fan Exit Louver End Cap Design Change

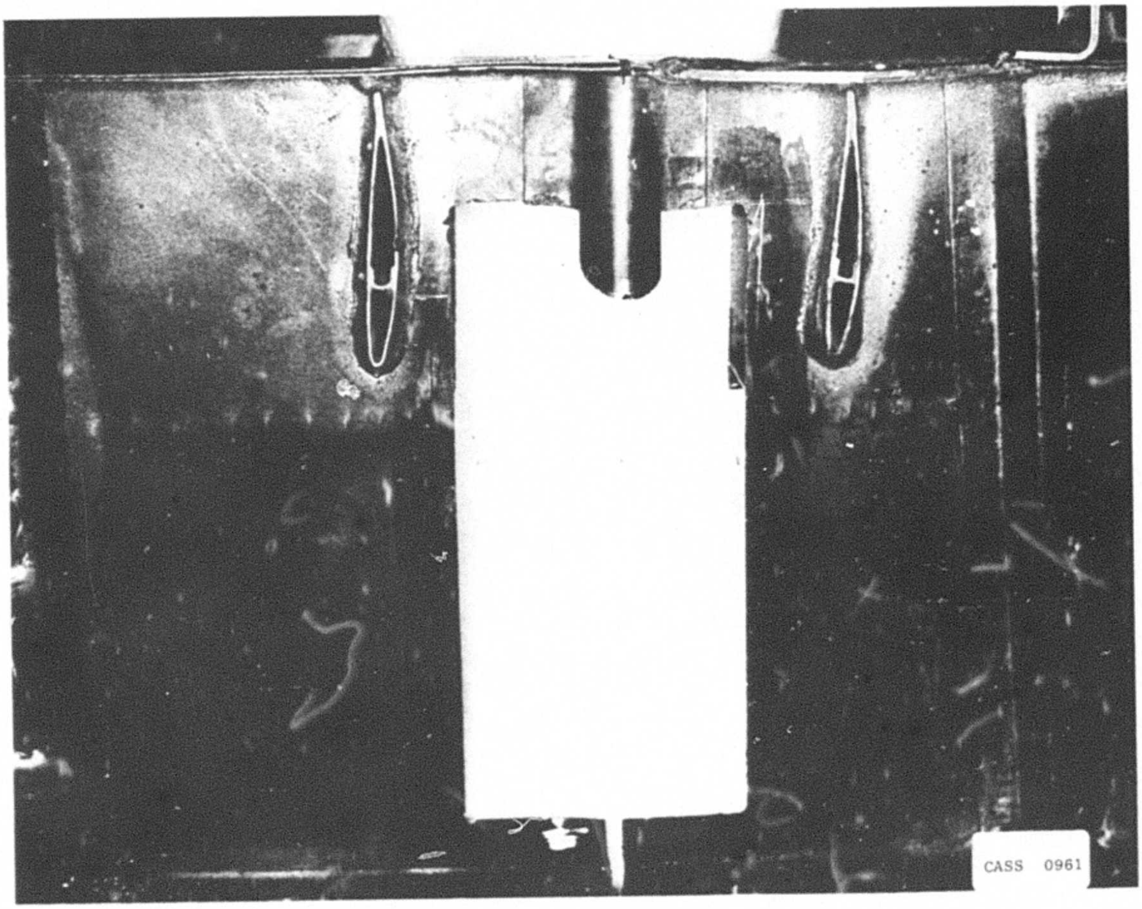


Figure 6 In-Process View of Scupper Installation

Figure 7 Inside View of Rear Frame Scupper

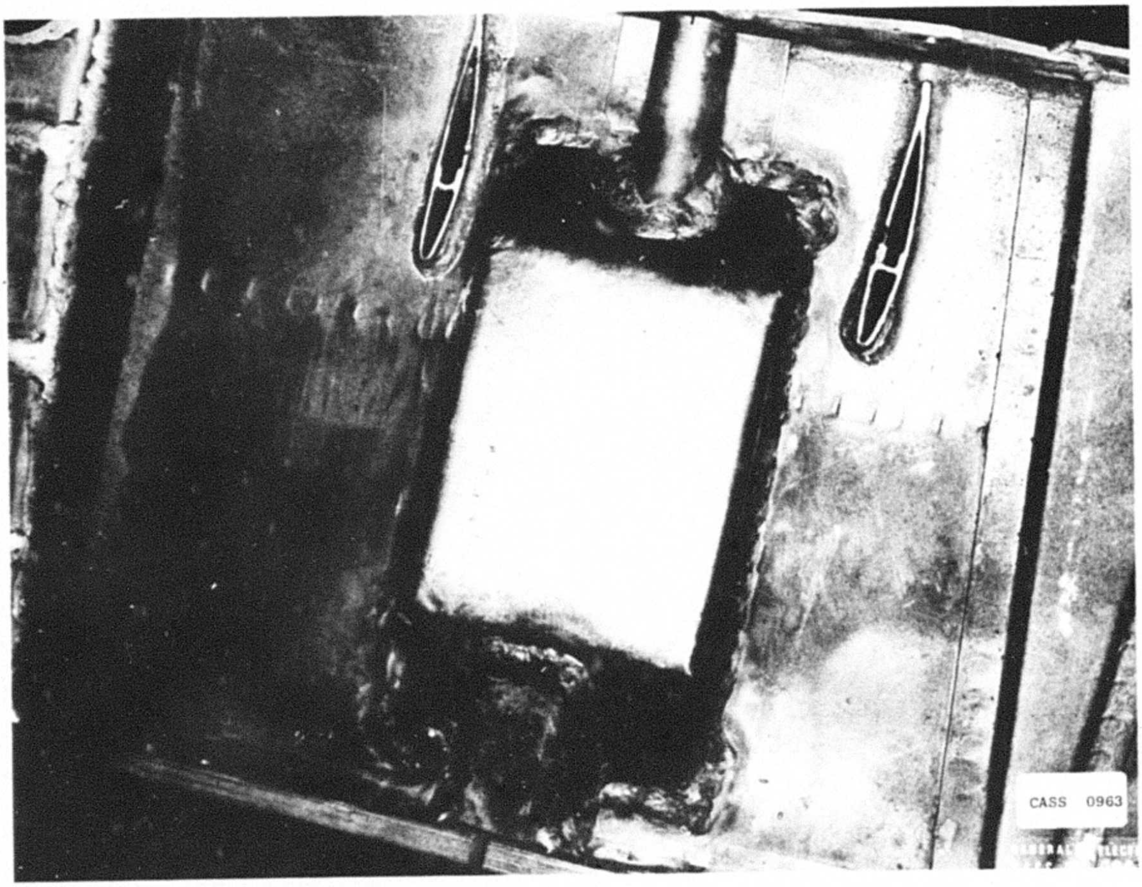


Figure 8   Outside View of Rear Frame Scupper

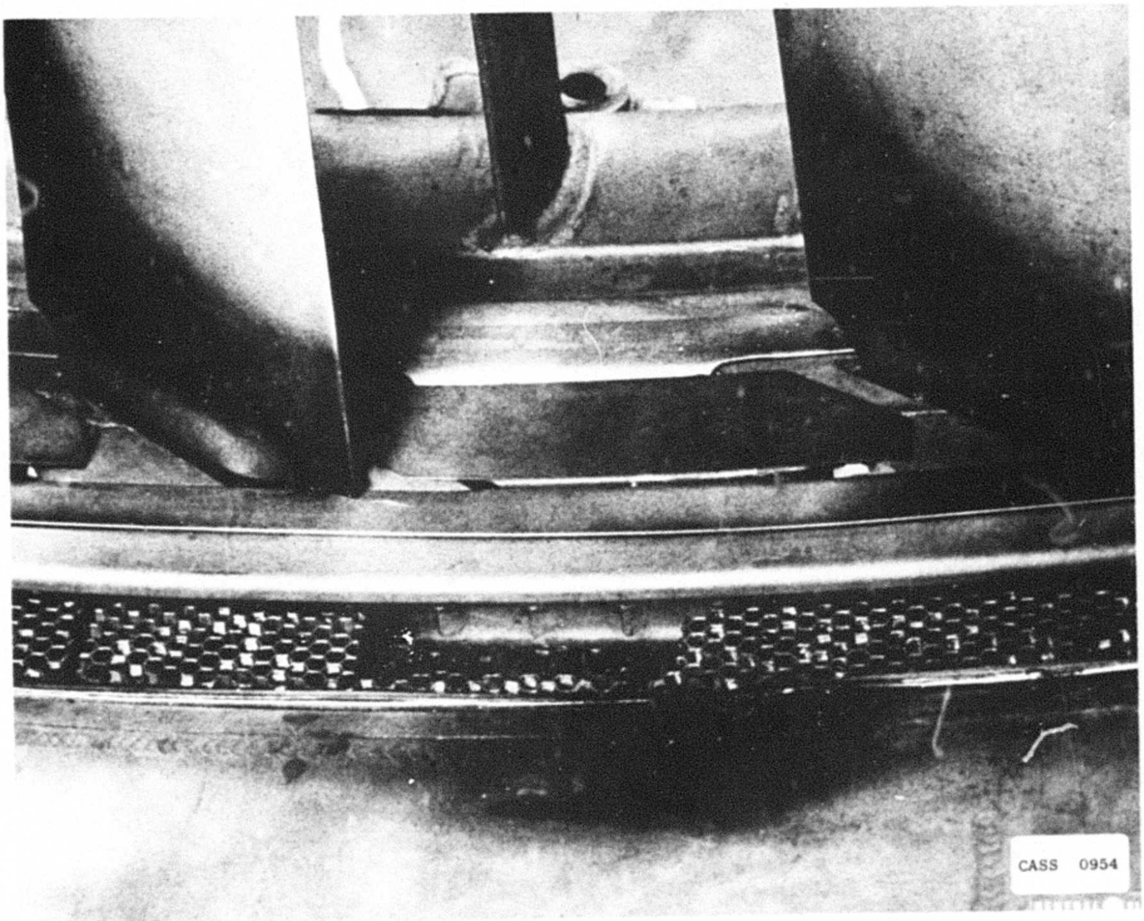


Figure 9   Recess in Forward Air Seal For Rotor Inspection

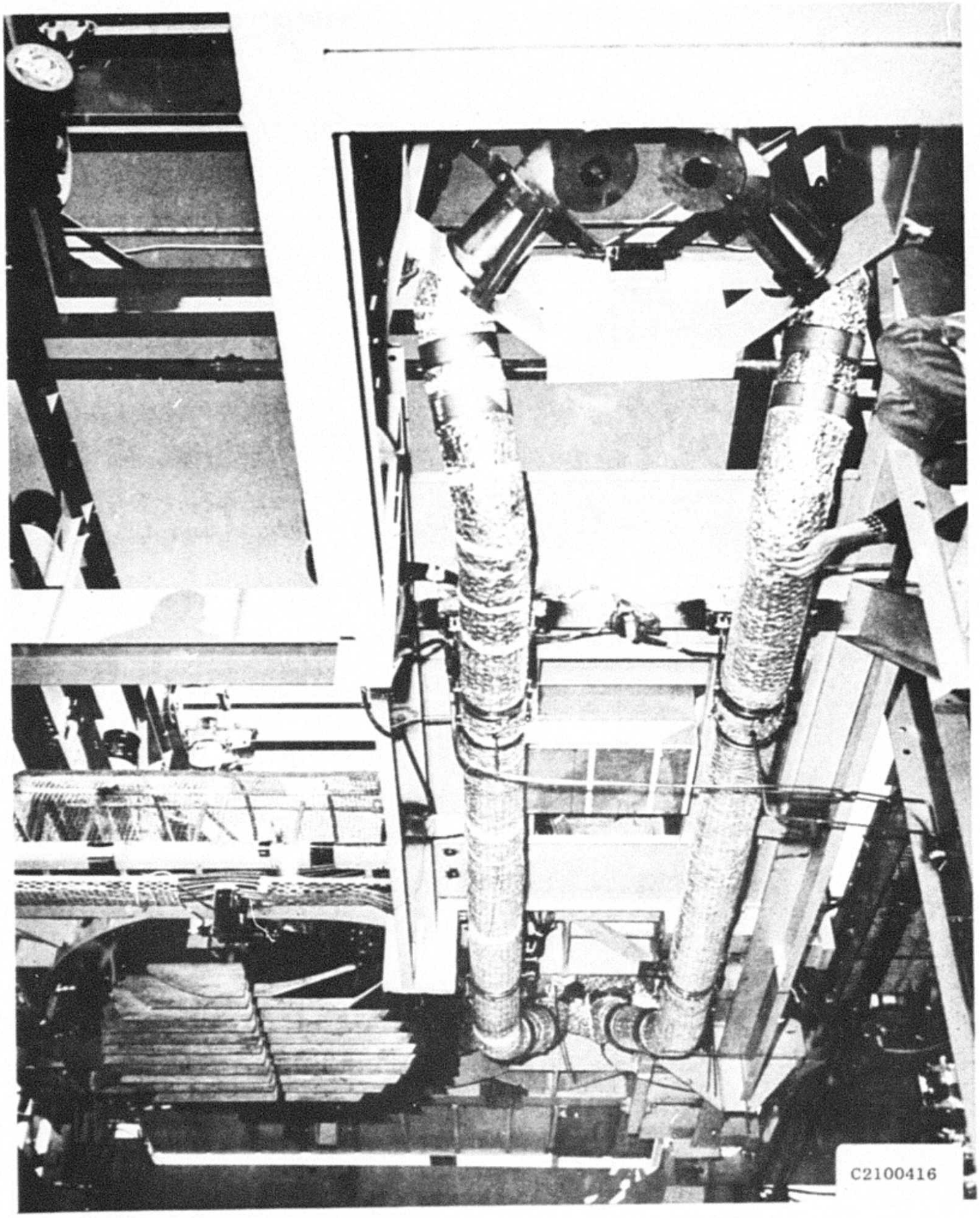


Figure 10 Pitch Fan Ducting (Simulator Ducts Installed)

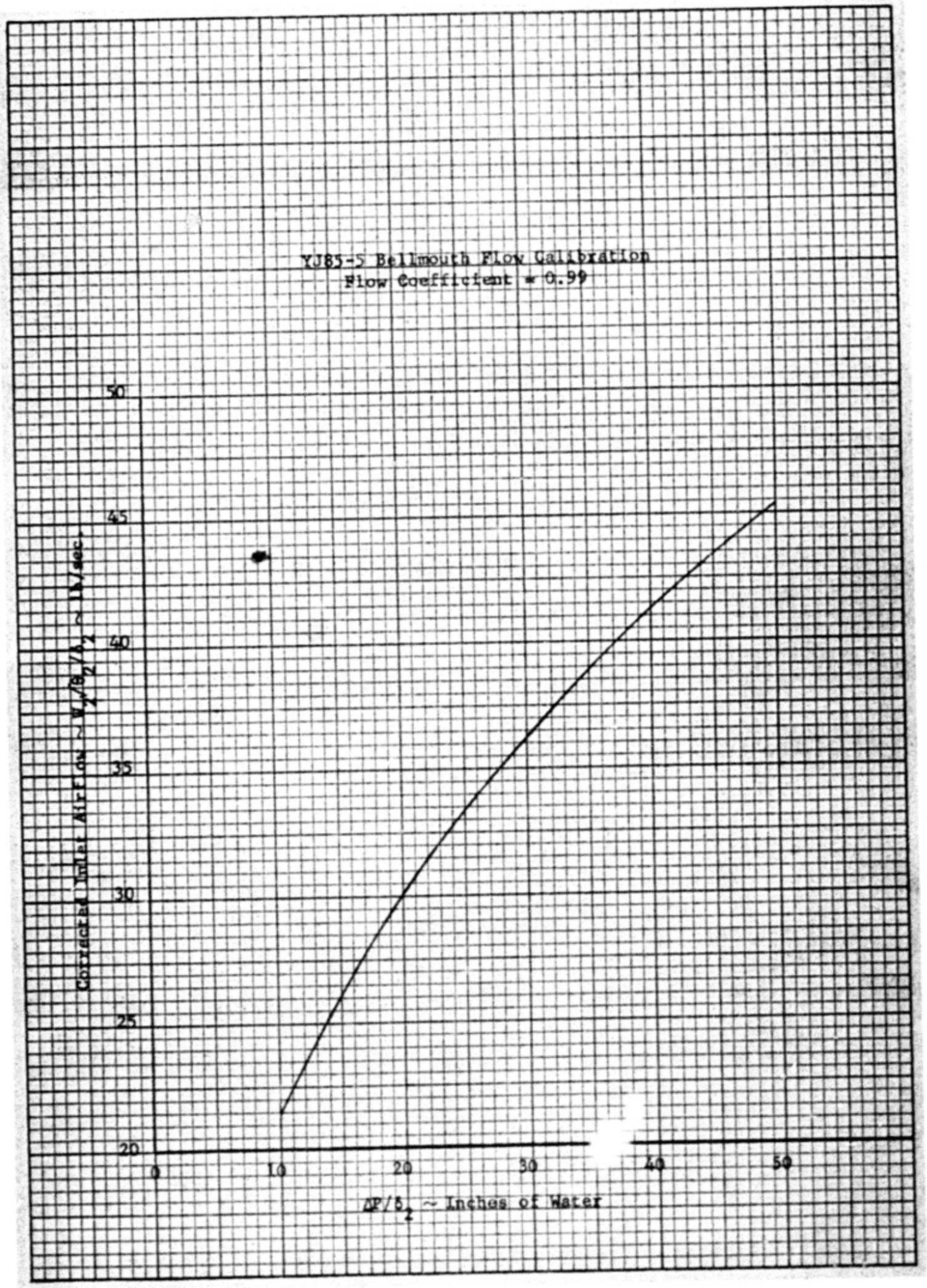


Figure 11   YJ85-5 Airflow Versus Inlet Static Pressure

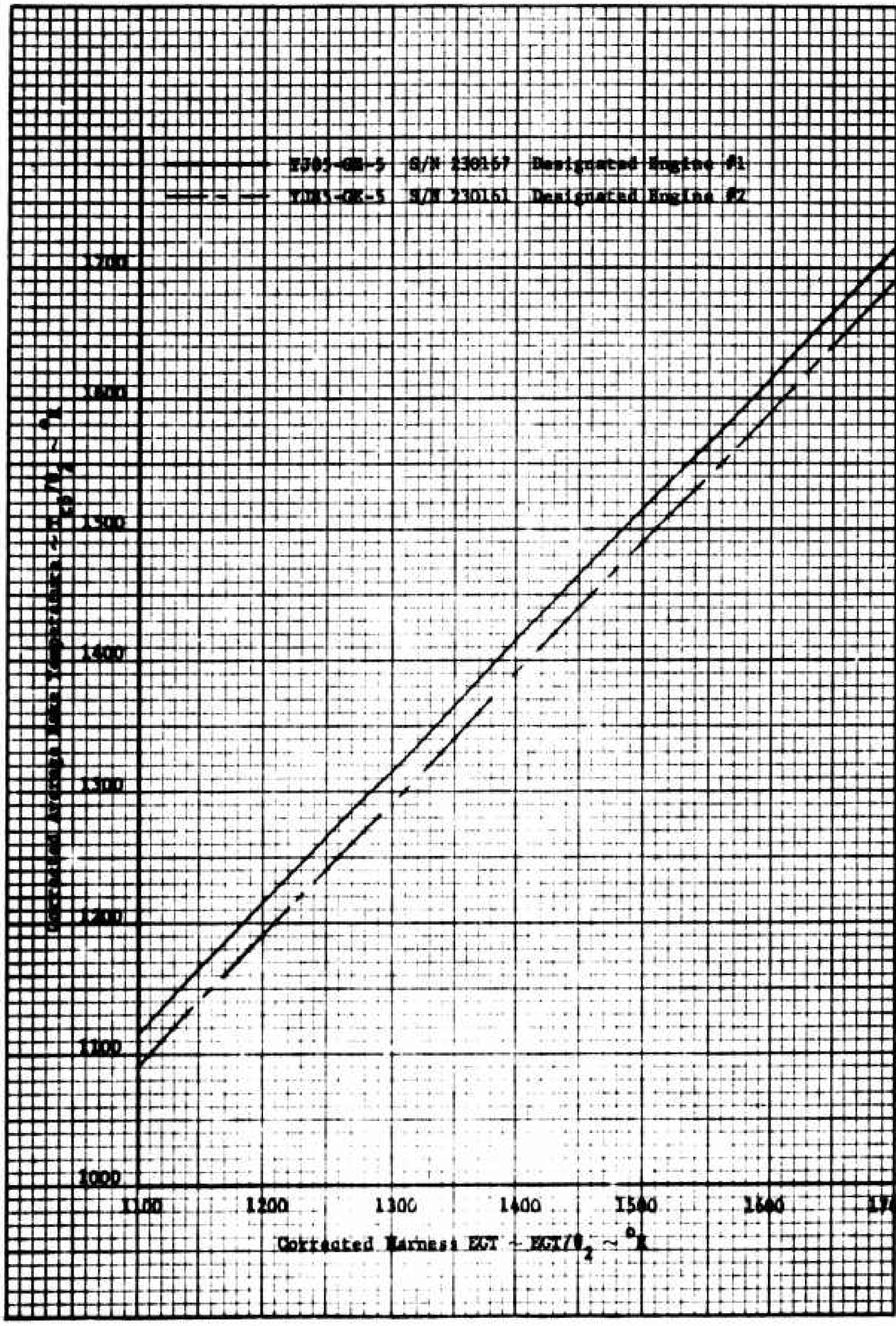


Figure 12 YJ85-5 EGT Harness Calibrations

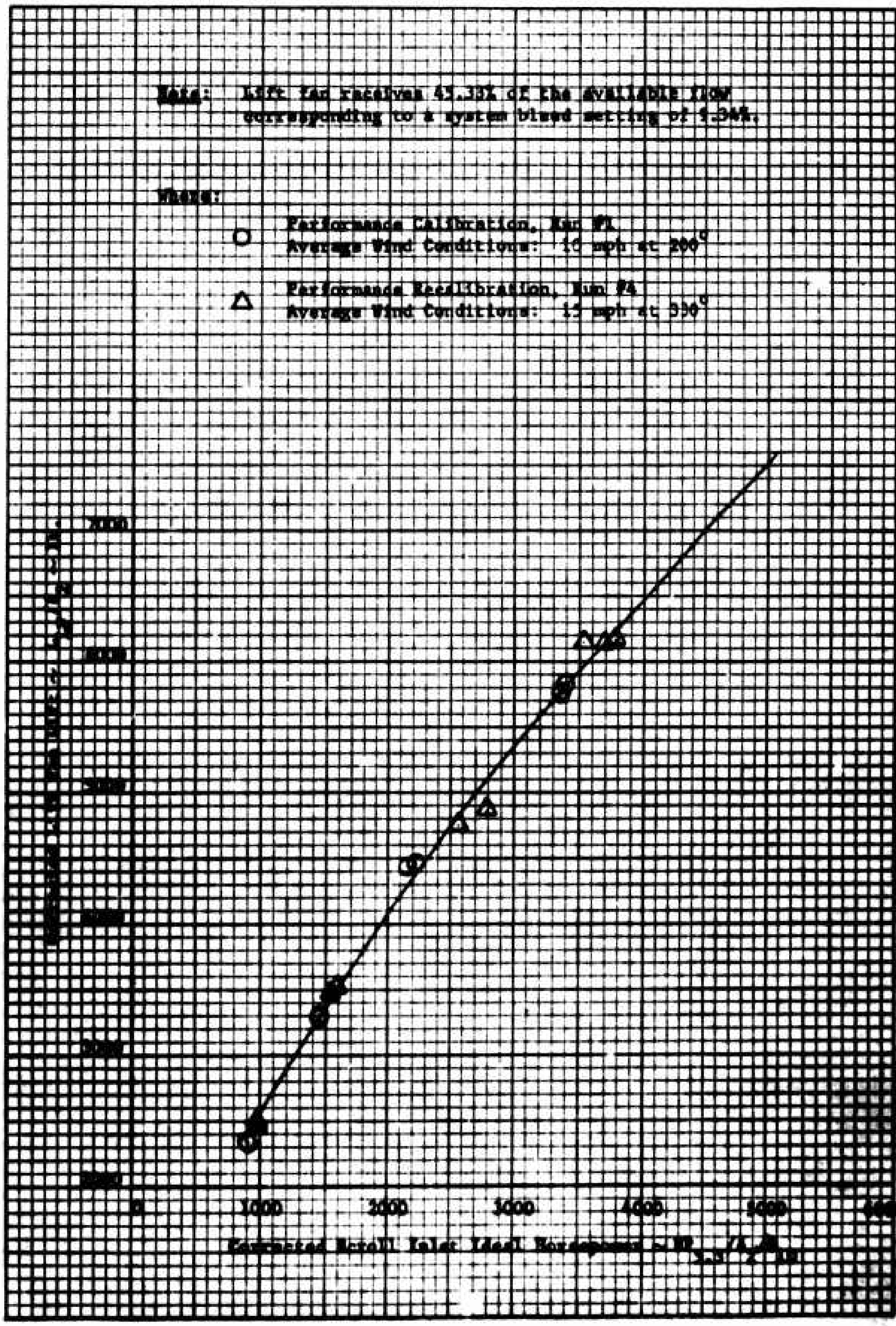


Figure 13 Lift Versus Scroll Inlet Ideal Horsepower

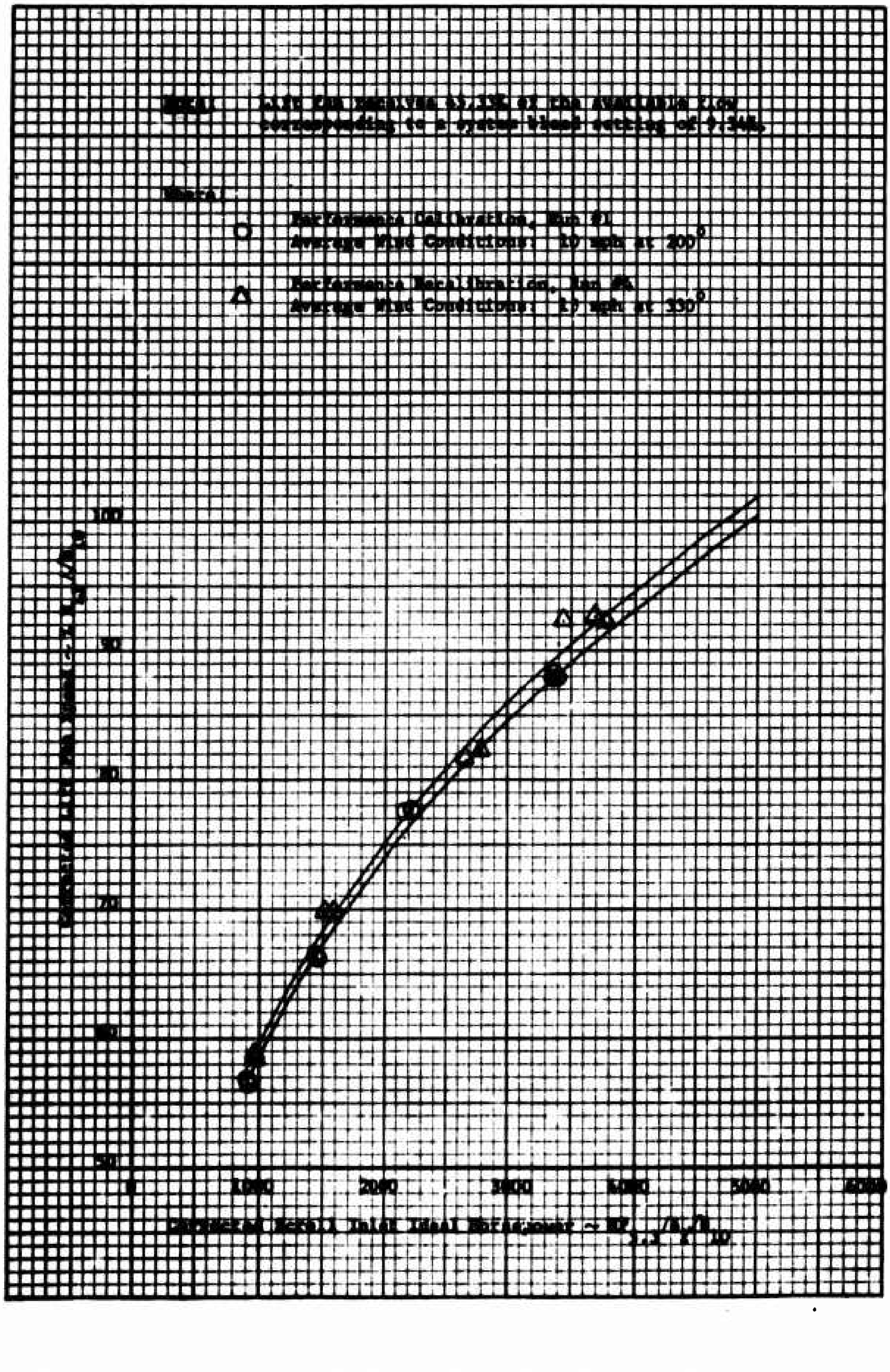


Figure 14 Fan Speed Versus Scroll Inlet Ideal Horsepower

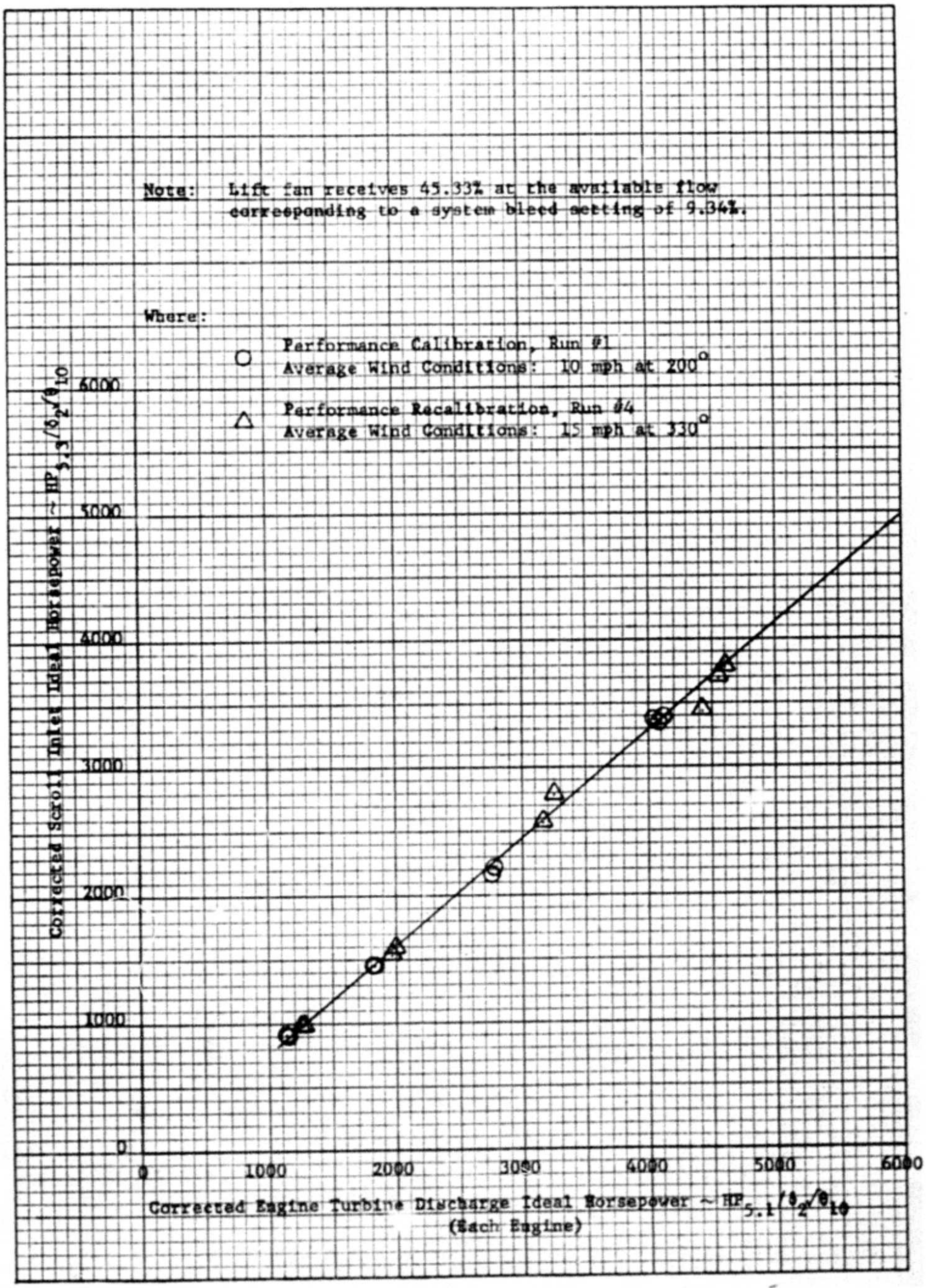


Figure 15 Gas Horsepower Available to Fan Versus Engine Power

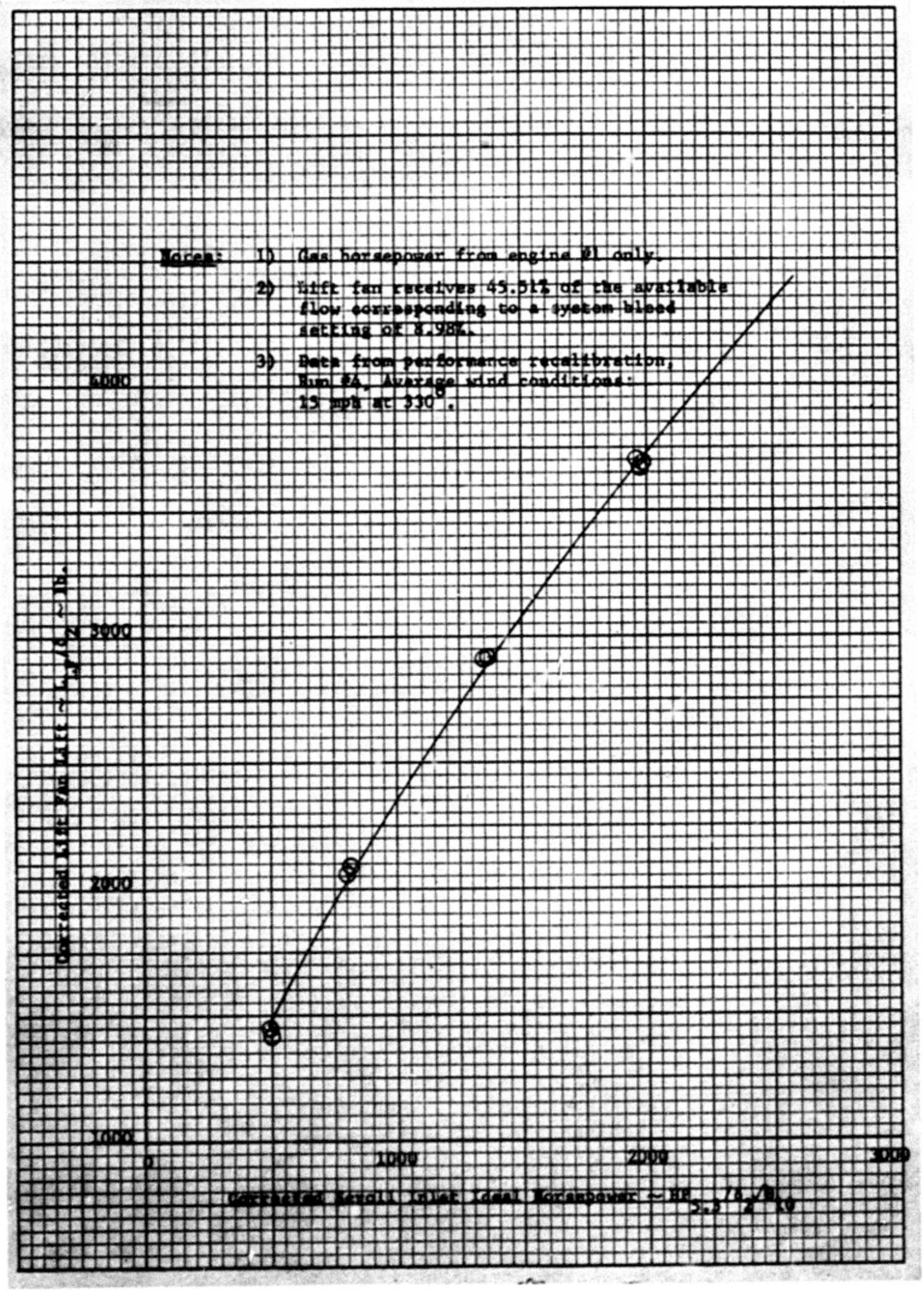


Figure 16 Lift Versus Scroll Inlet Ideal Horsepower (Engine #1 Only)

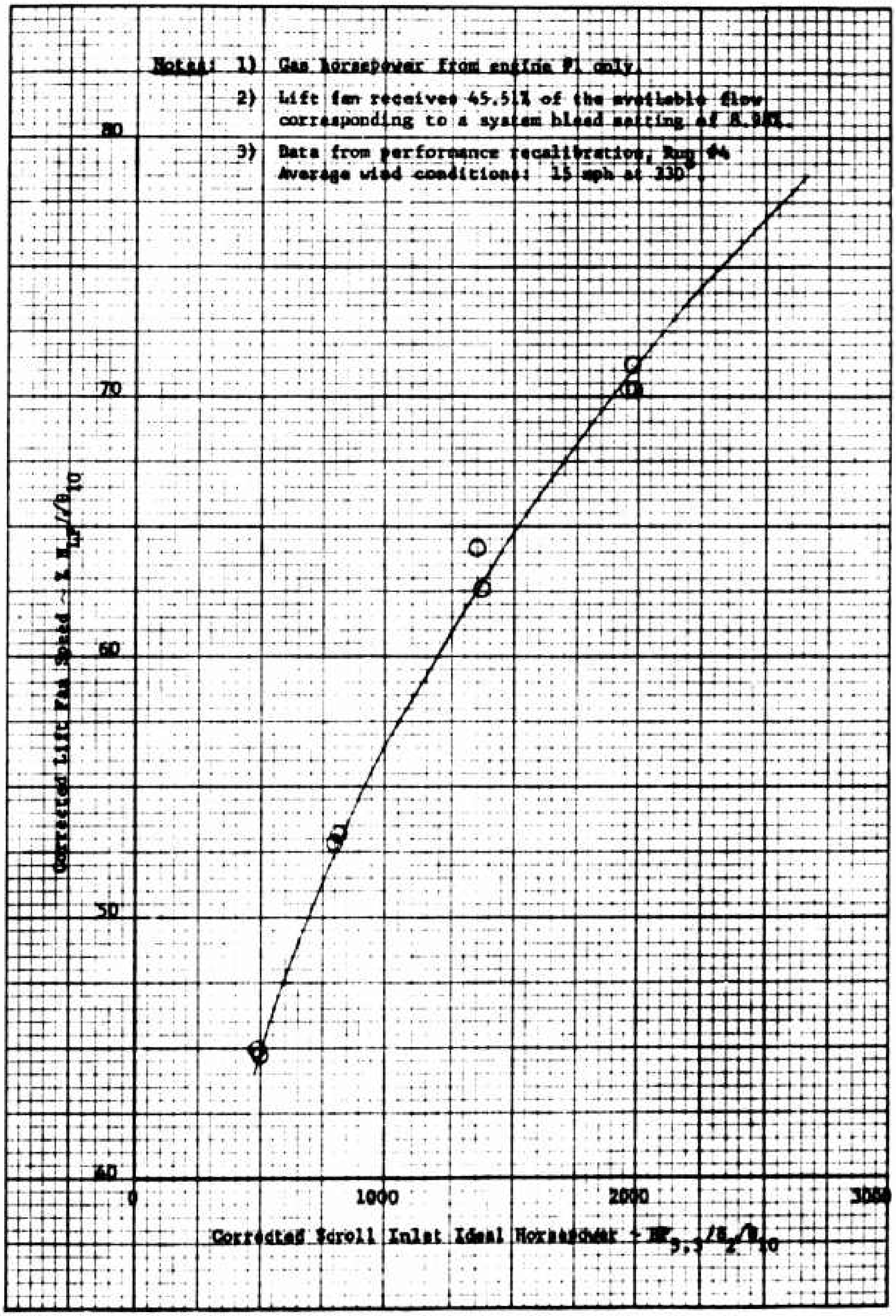


Figure 17 Fan Speed Versus Scroll Inlet Ideal Horsepower (Engine #1 Only)

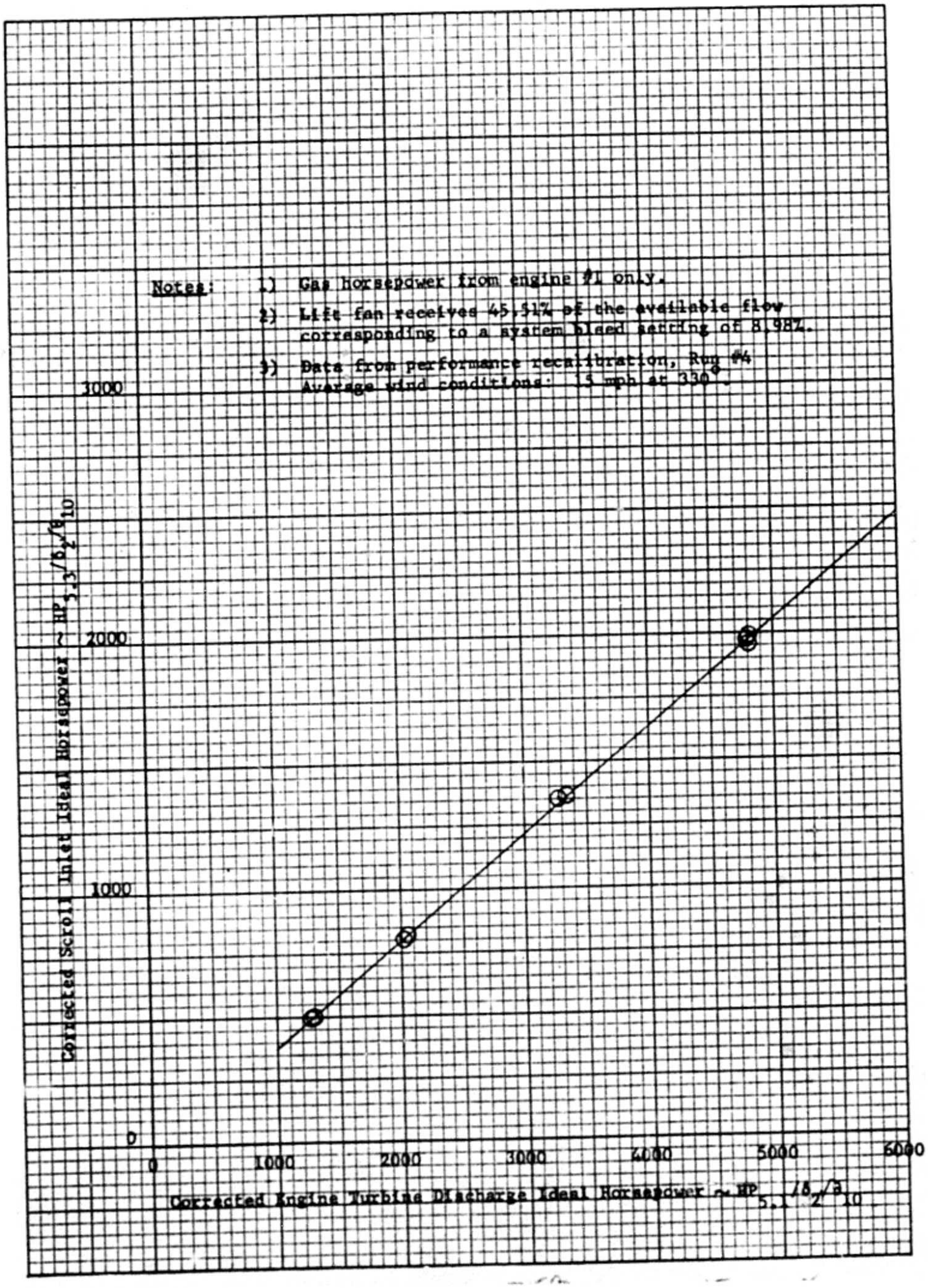


Figure 18 Gas Horsepower Available to Fan Versus Engine Power #1 Only)

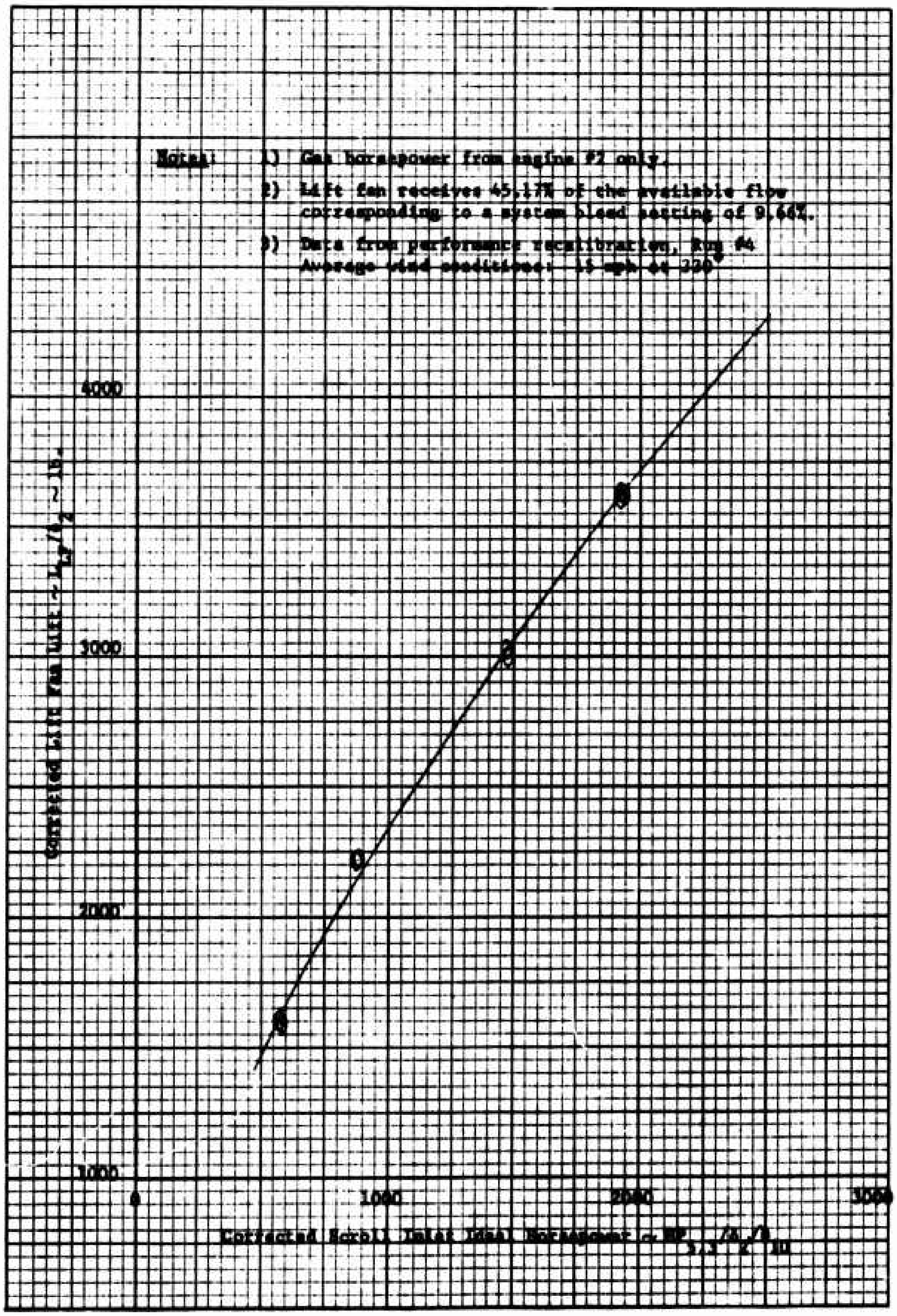


Figure 19 Lift Versus Scroll Inlet Ideal Horsepower (Engine #2 Only)

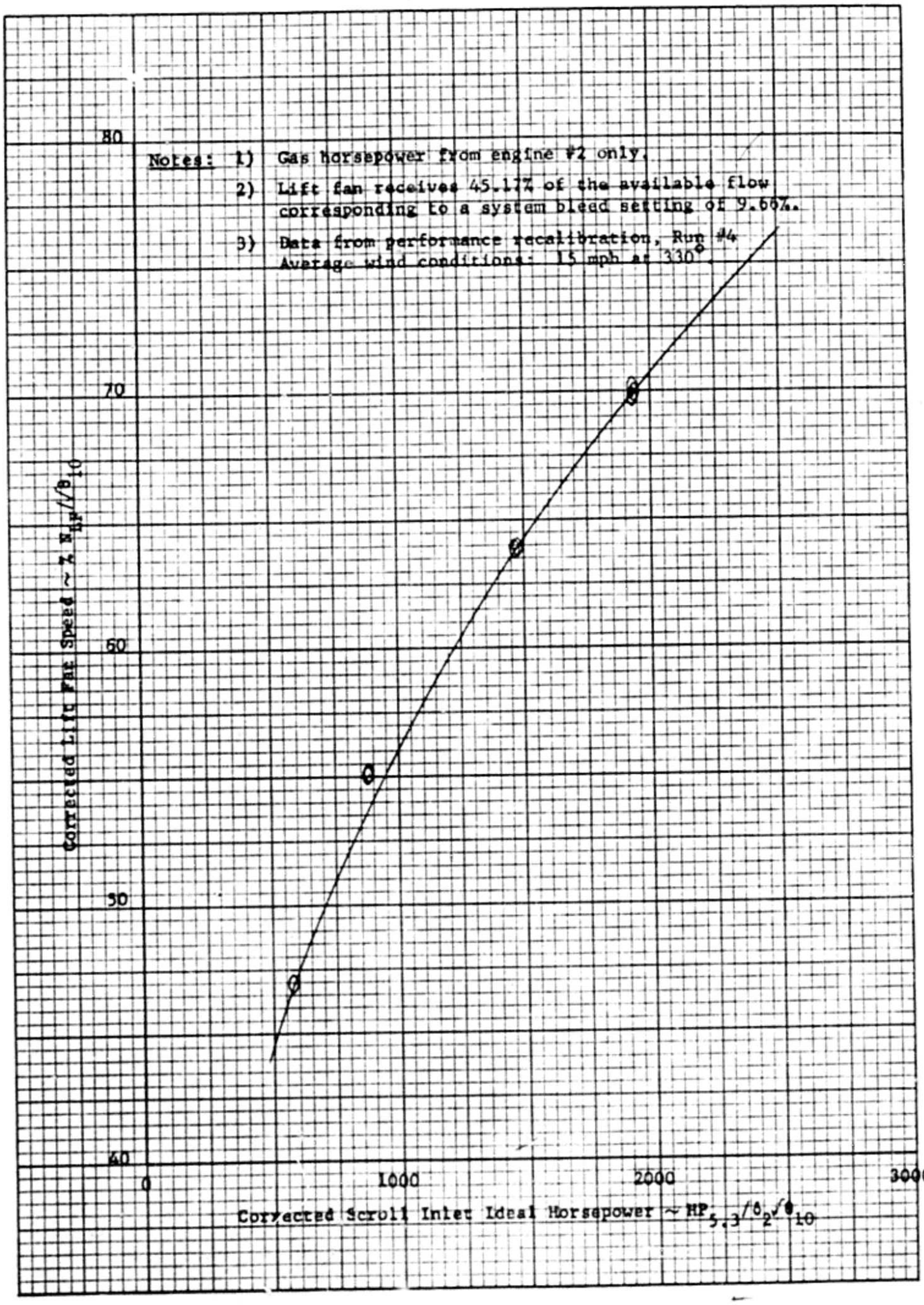


Figure 20 Fan Speed Versus Scroll Inlet Ideal Horsepower (Engine #2 Only)

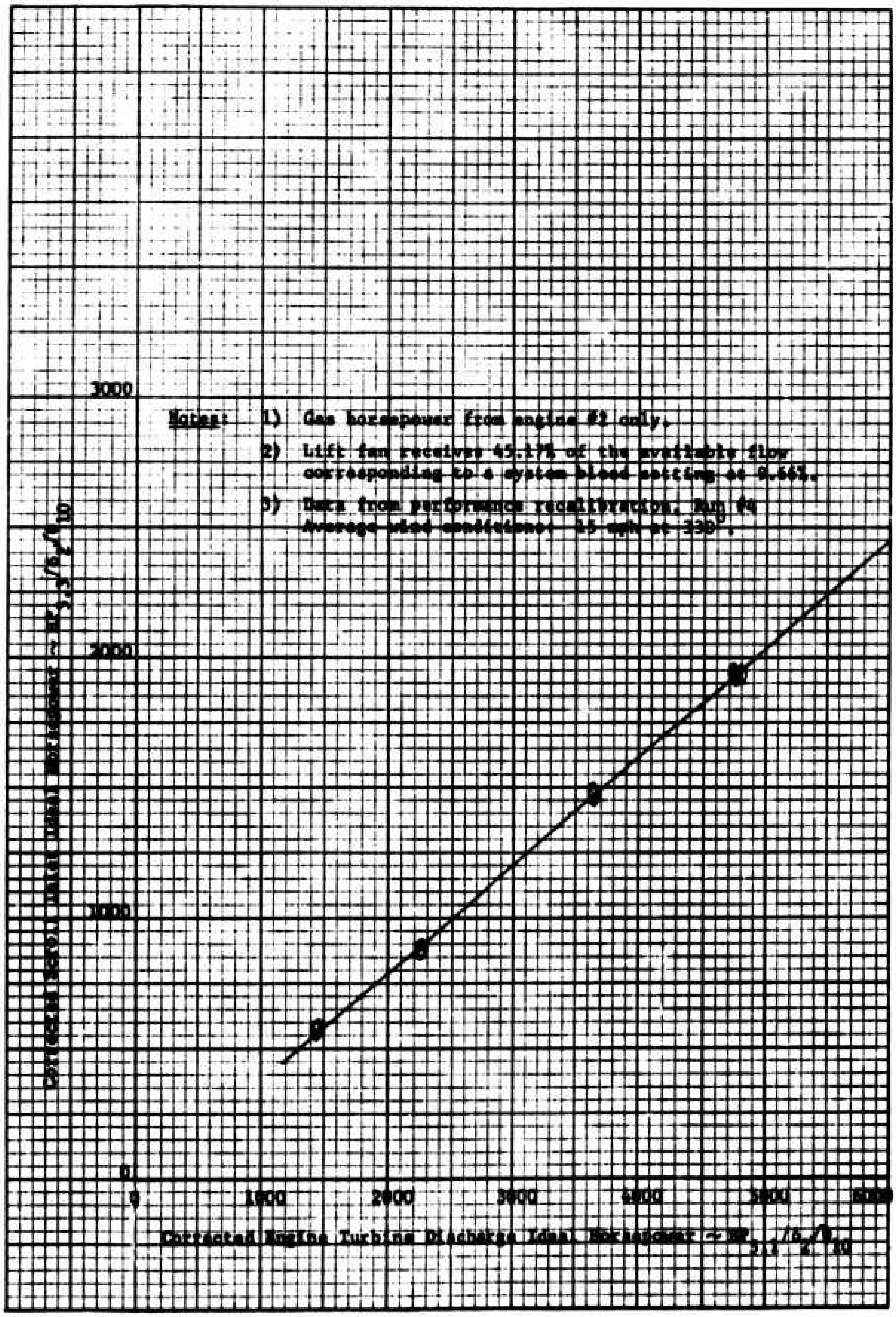


Figure 21 Gas Horsepower Available to Fan Versus Engine Power (Engine #2 Only)

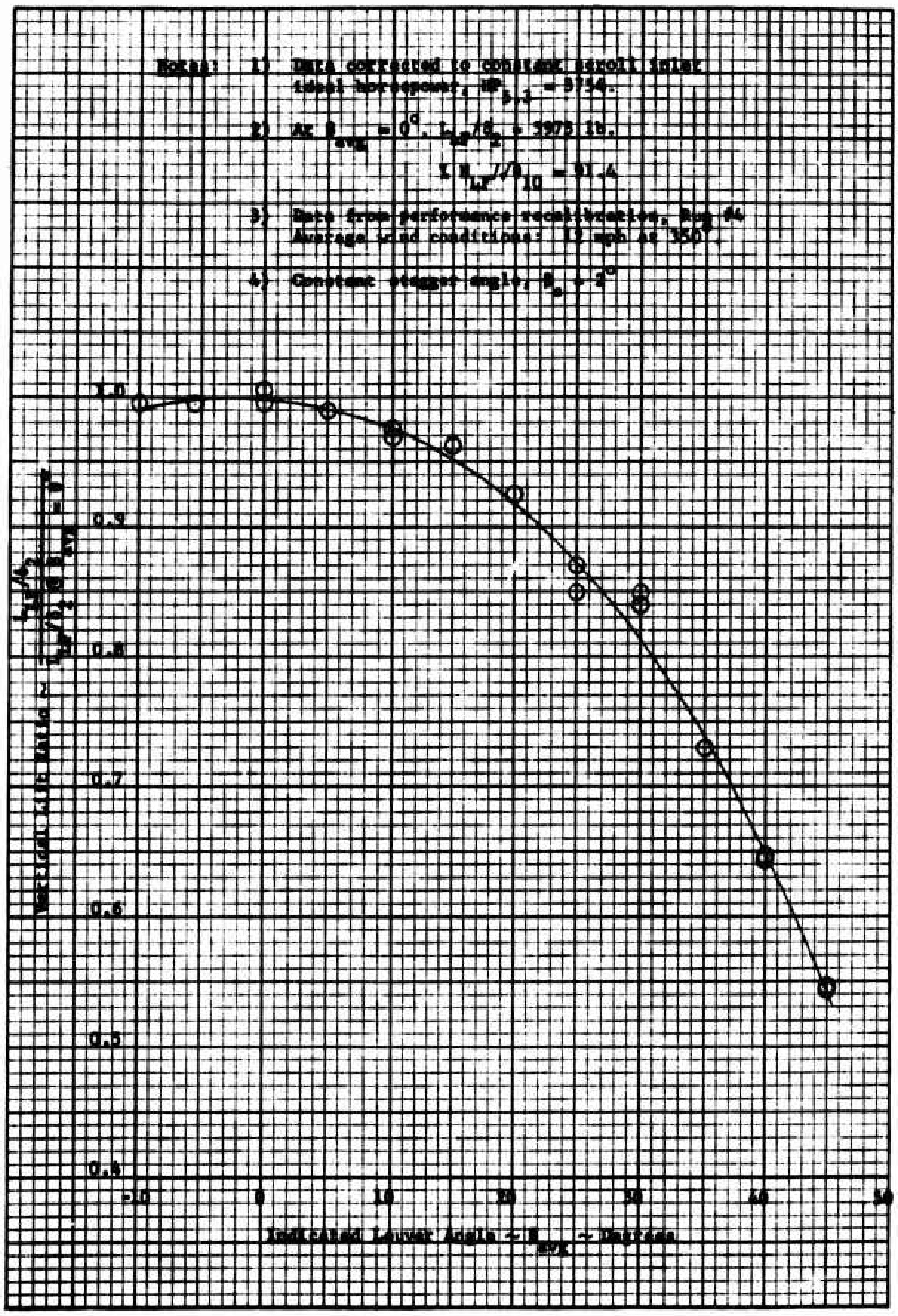


Figure 22   Vertical Lift Ratio Versus Indicated Louver Angle

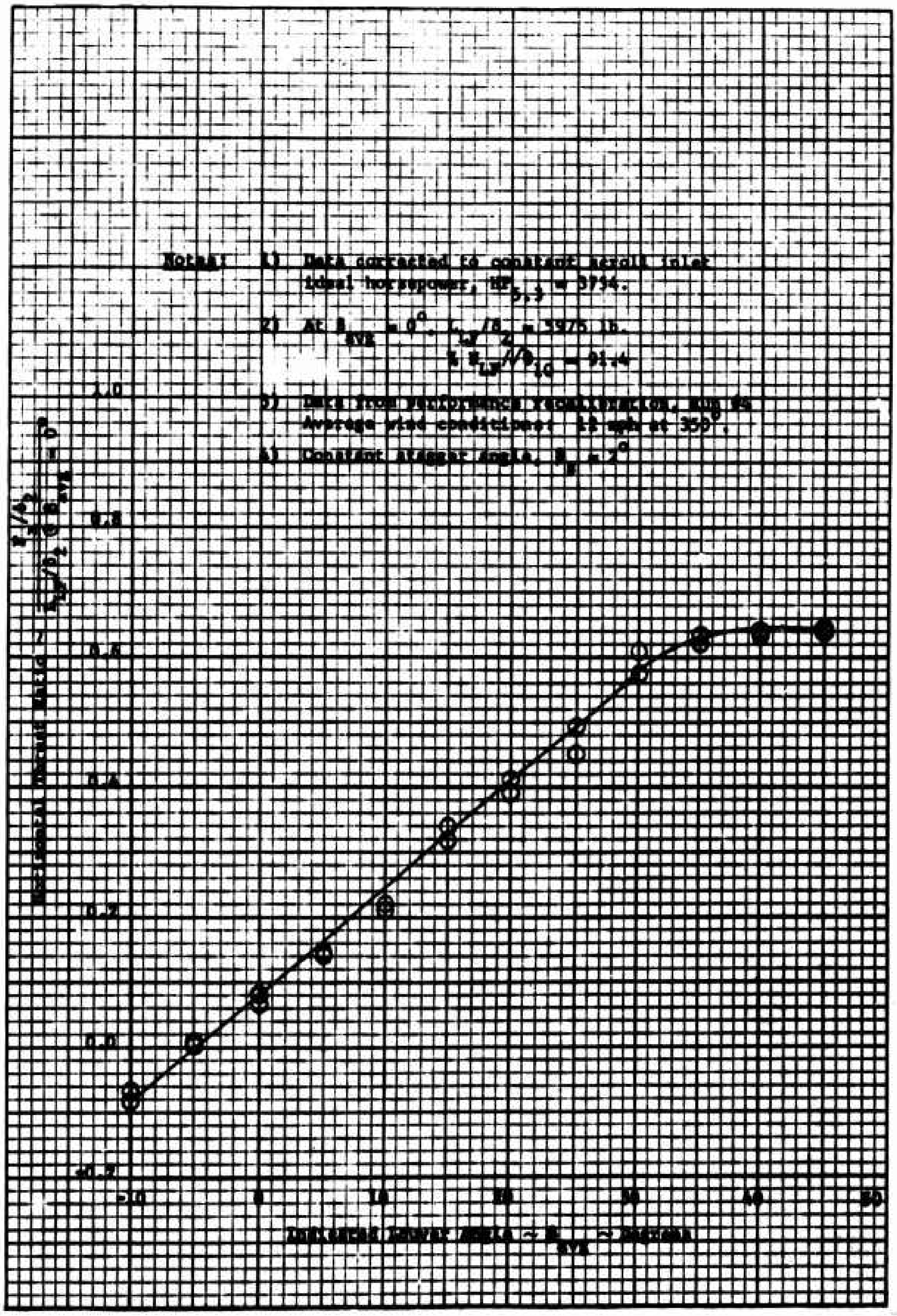


Figure 23 Horizontal Thrust Ratio Versus Indicated Louver Angle

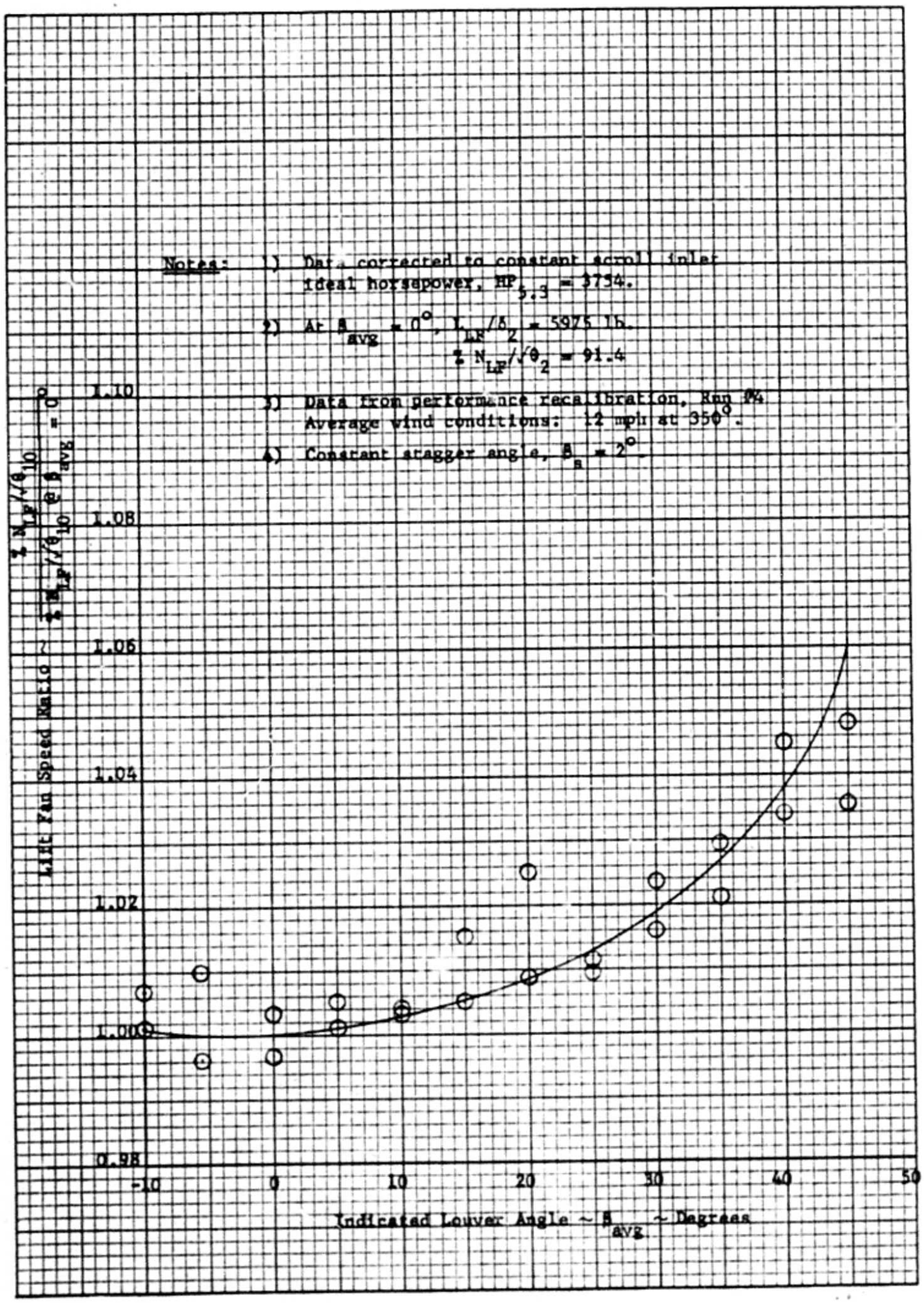


Figure 24   Lift Fan Speed Ratio Versus Indicated Louver Angle

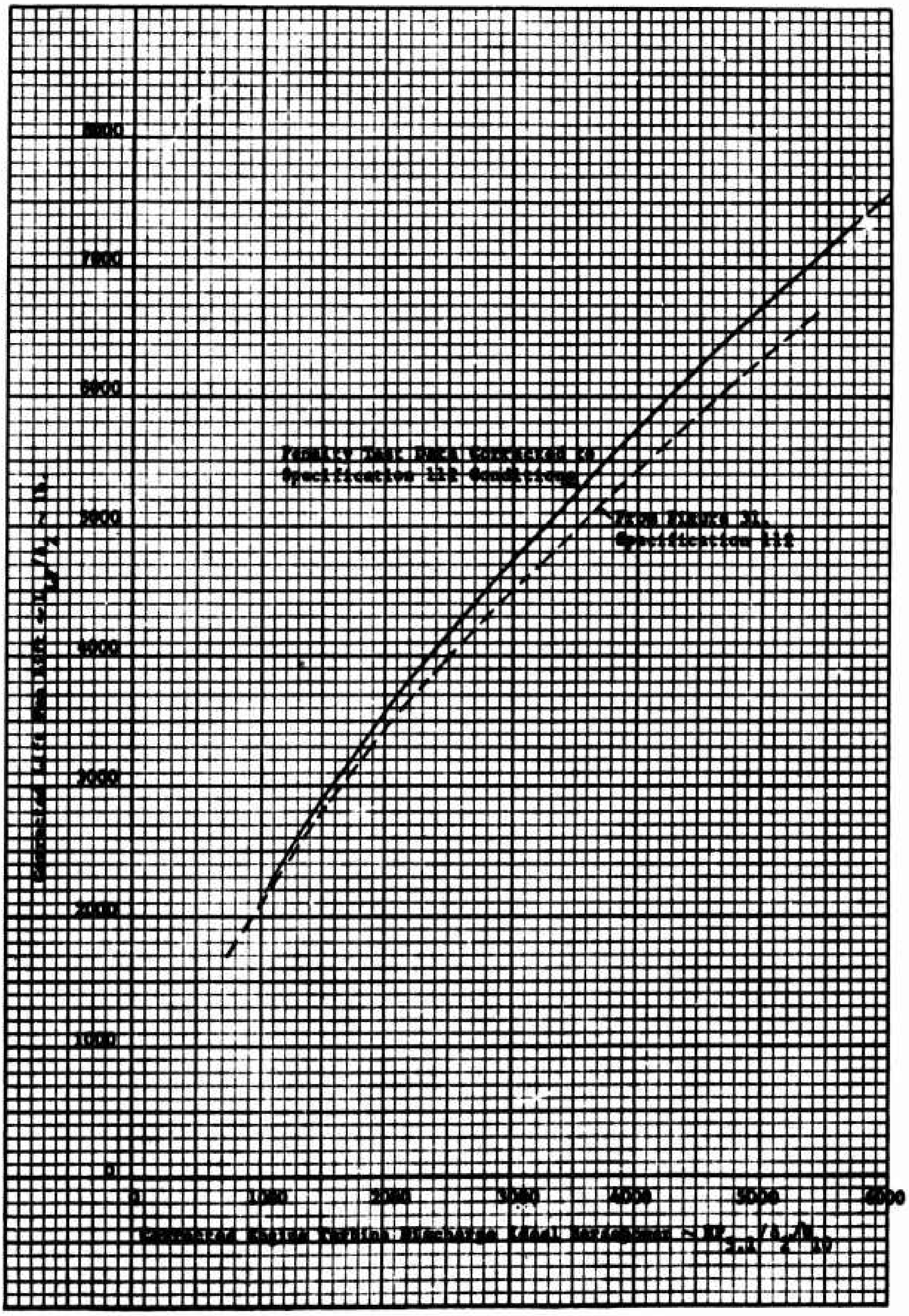


Figure 25 Lift Versus Engine Turbine Discharge Ideal Horsepower (Corrected to Specification 112 Conditions at 10.6% Bleed)

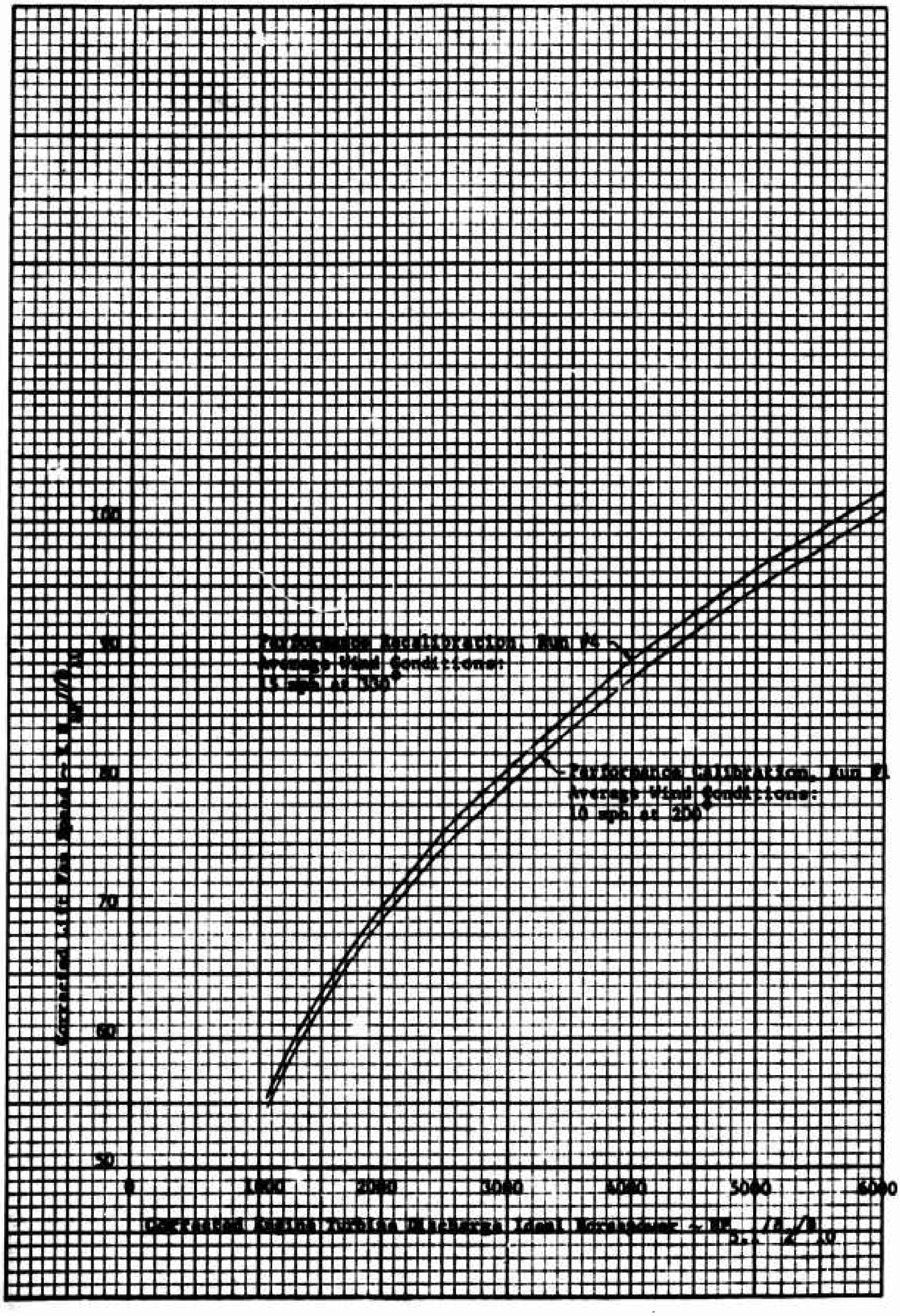


Figure 26 Fan Speed Versus Engine Turbine Discharge Ideal Horsepower (Corrected to Specification 112 Conditions at 10.6% Bleed)

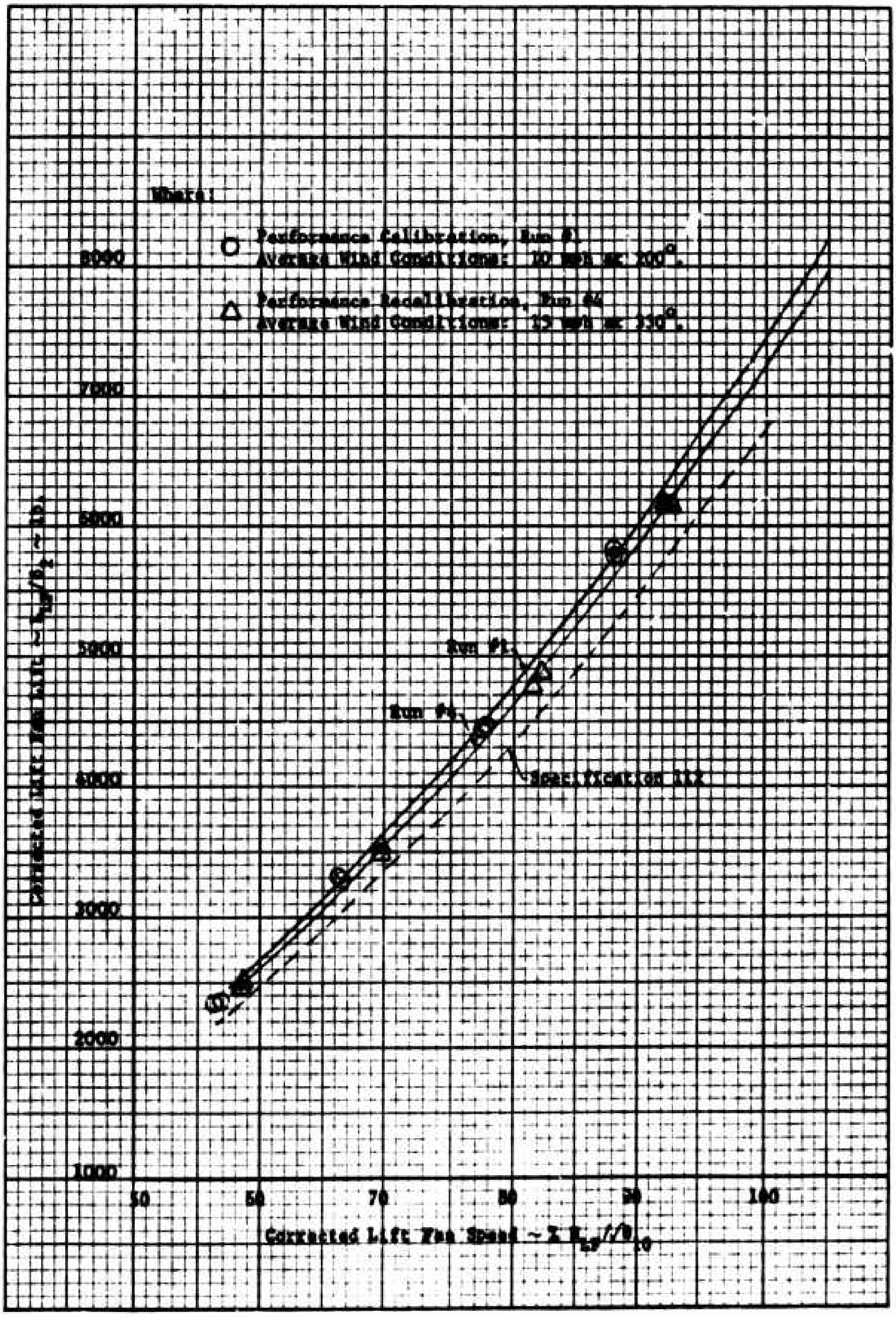


Figure 27 Comparison of Lift Fan 007L Speed-Lift Characteristic with Specification 112 ($\beta_V = 0^\circ$)

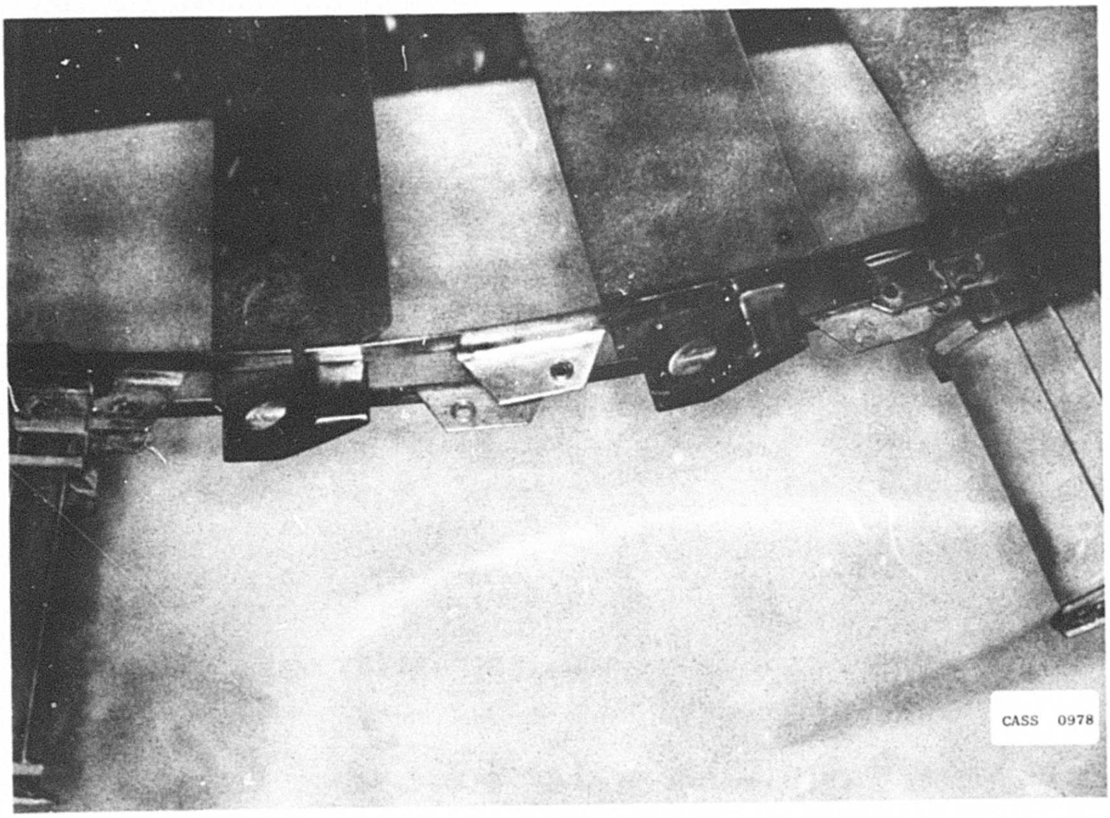


Figure 28 Torque Band Condition After Penalty Test

Figure 29 Seal Condition After Penalty Test

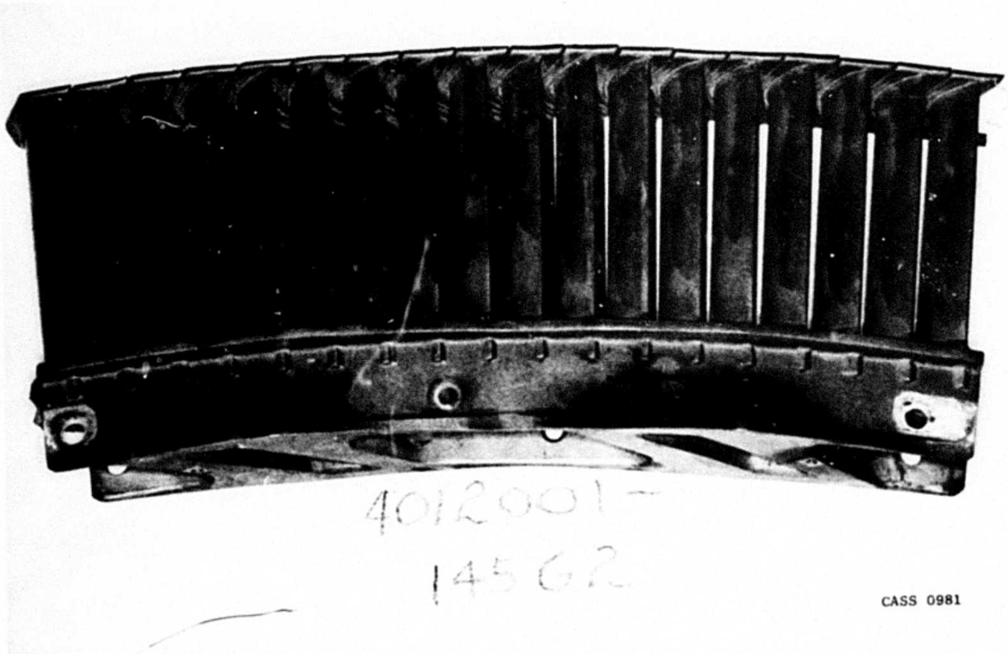


Figure 30 Bucket Carrier Condition After Penalty Test (Top Side)

Figure 31 Bucket Carrier Condition After Penalty Test (Bottom Side)

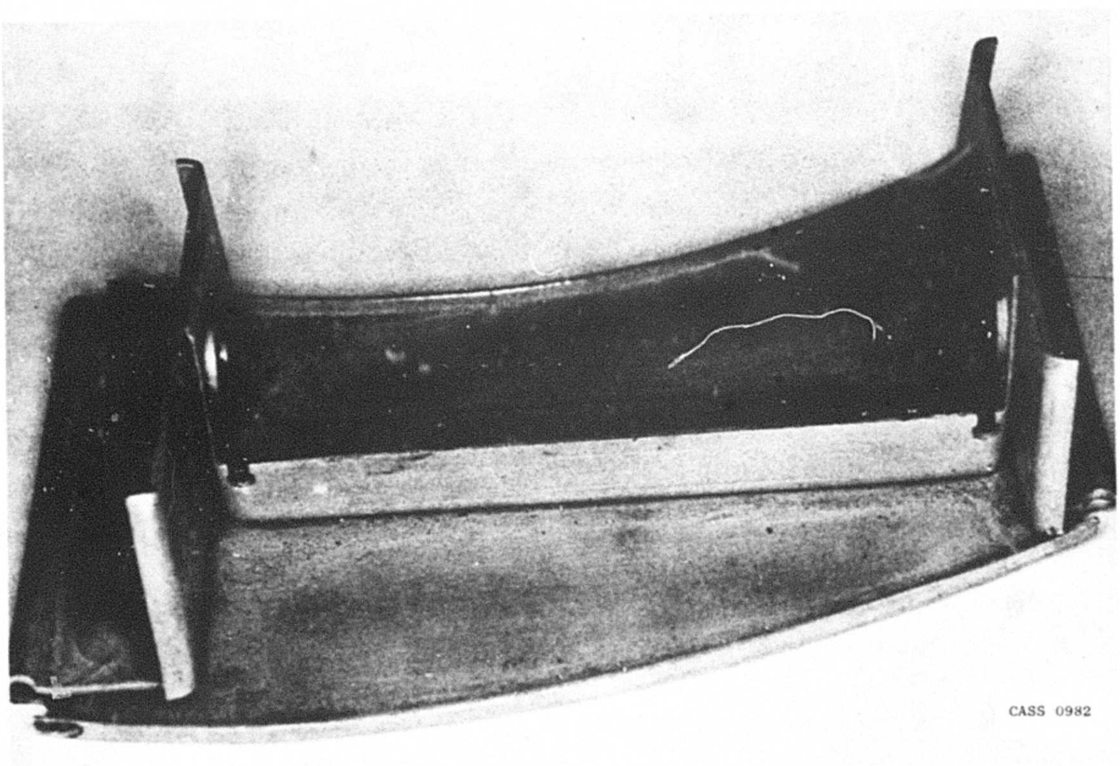


Figure 32 Platform Condition After Penalty Test

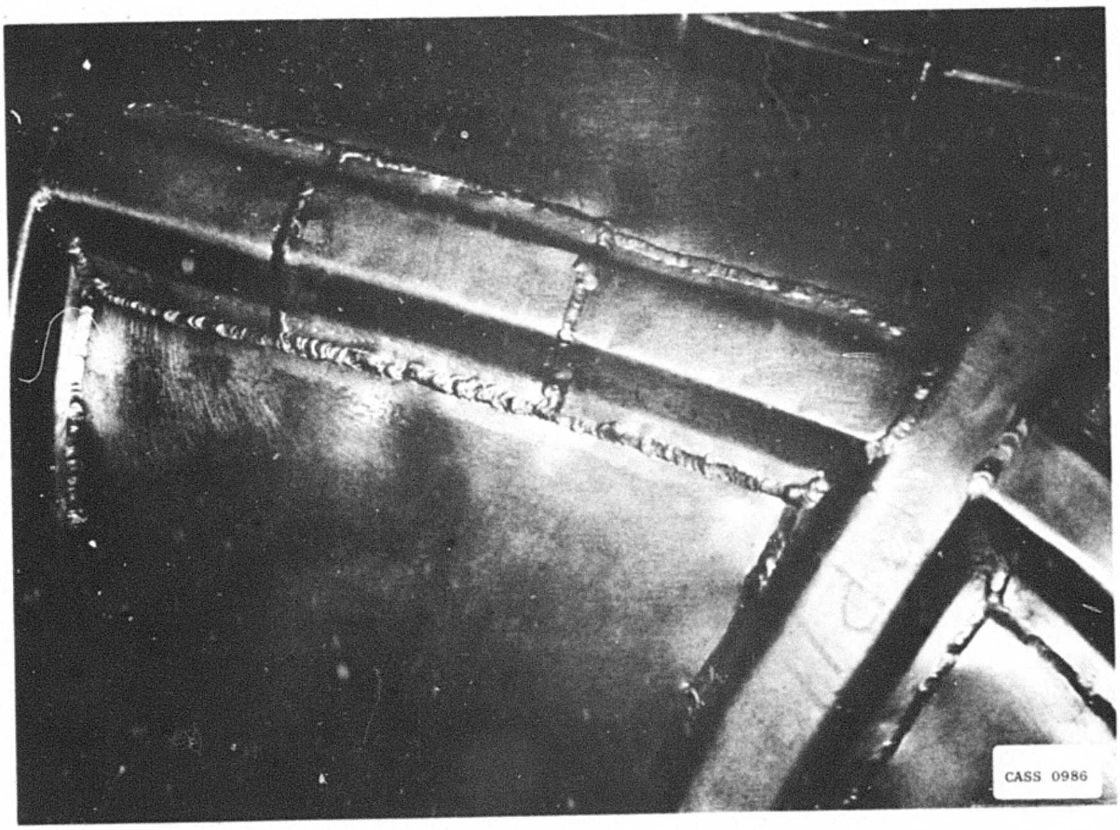


Figure 33 Scroll Where Hat Section was Added Showing Condition After Penalty Test

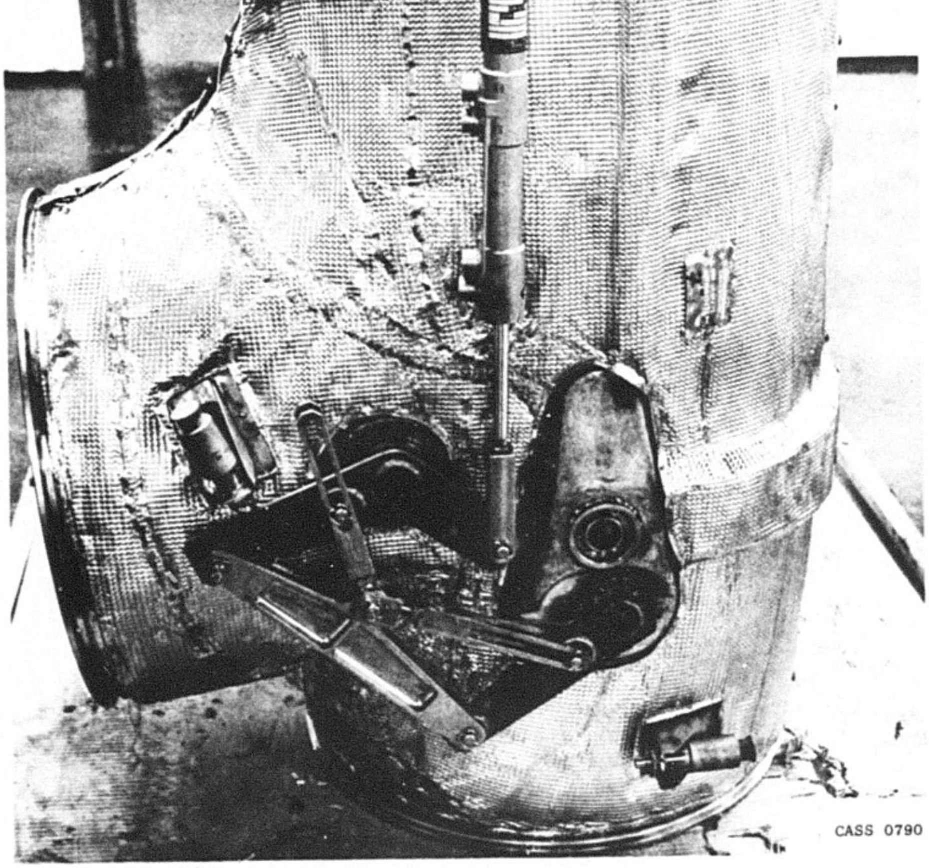
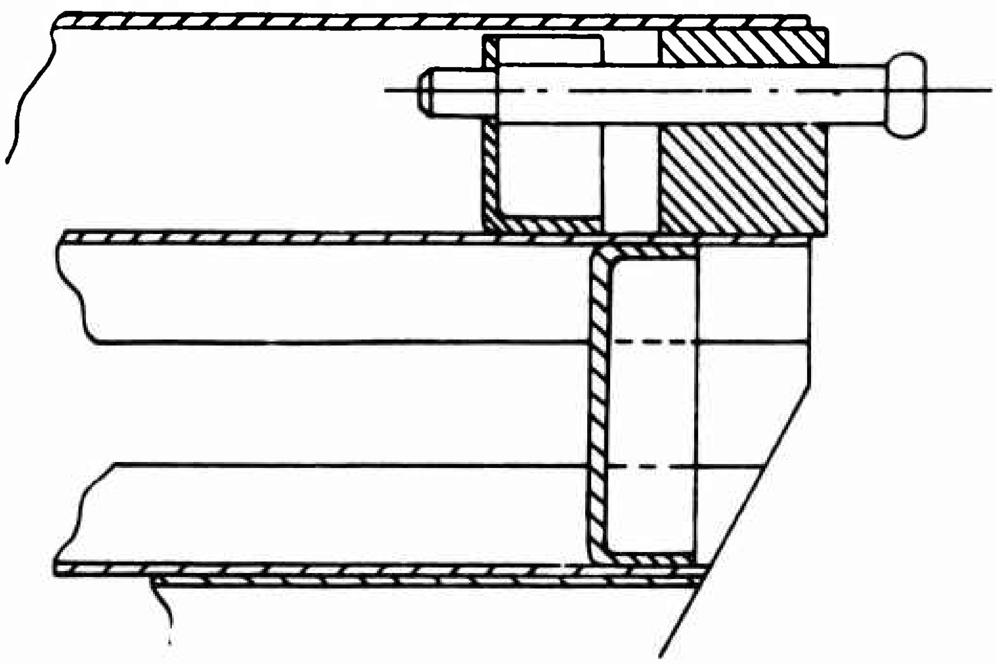
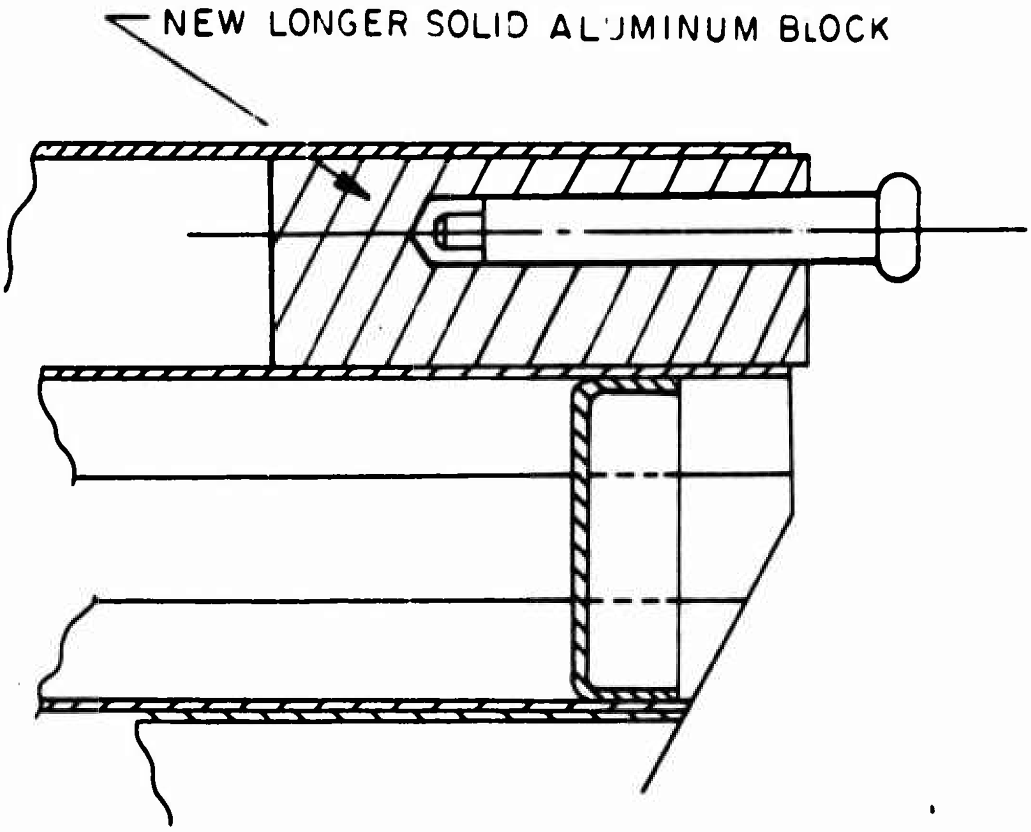


Figure 34 Flight Type Actuator for Diverter Valve



OLD OUTBOARD PIN ATTACHMENT DESIGN



NEW OUTBOARD PIN ATTACHMENT DESIGN

Figure 35 Lift Fan Exit Louver Outboard Pin Attachment Design Change (Louvers 34, 35 and 36)